

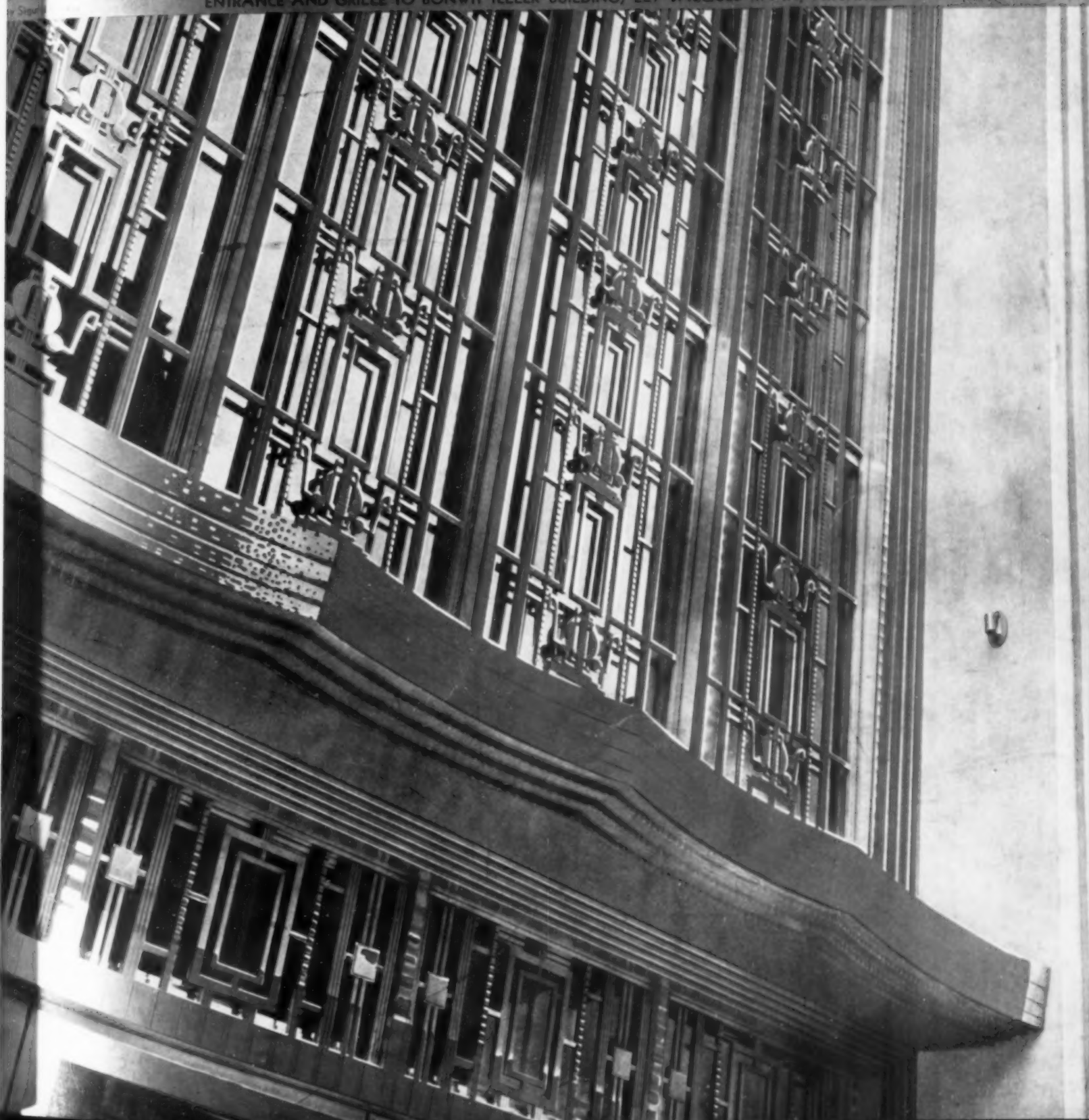
# METAL

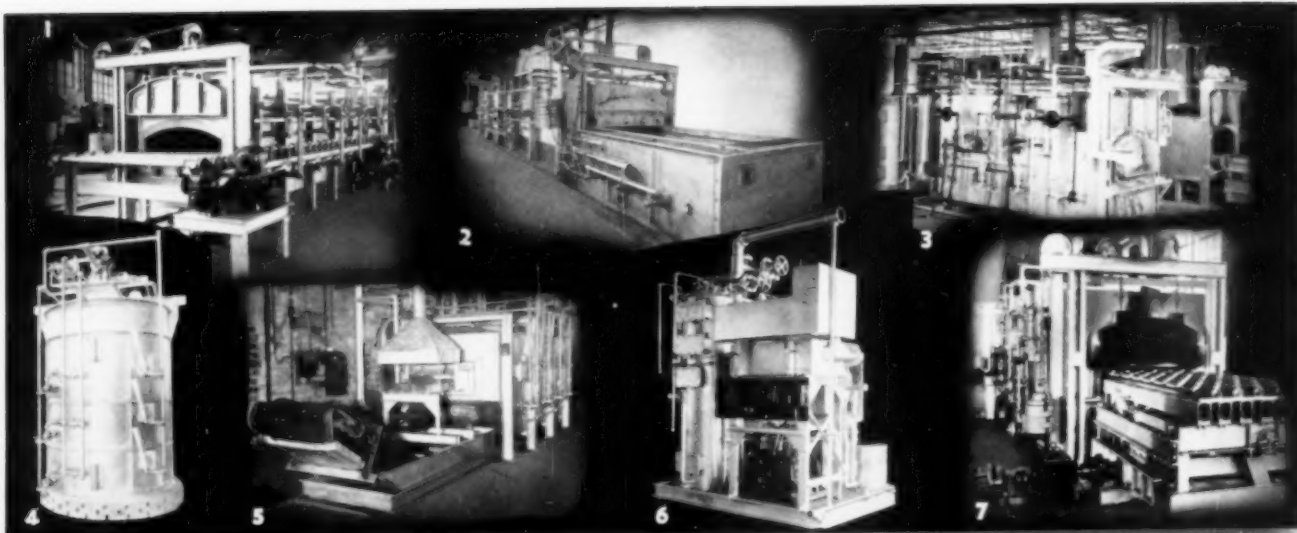
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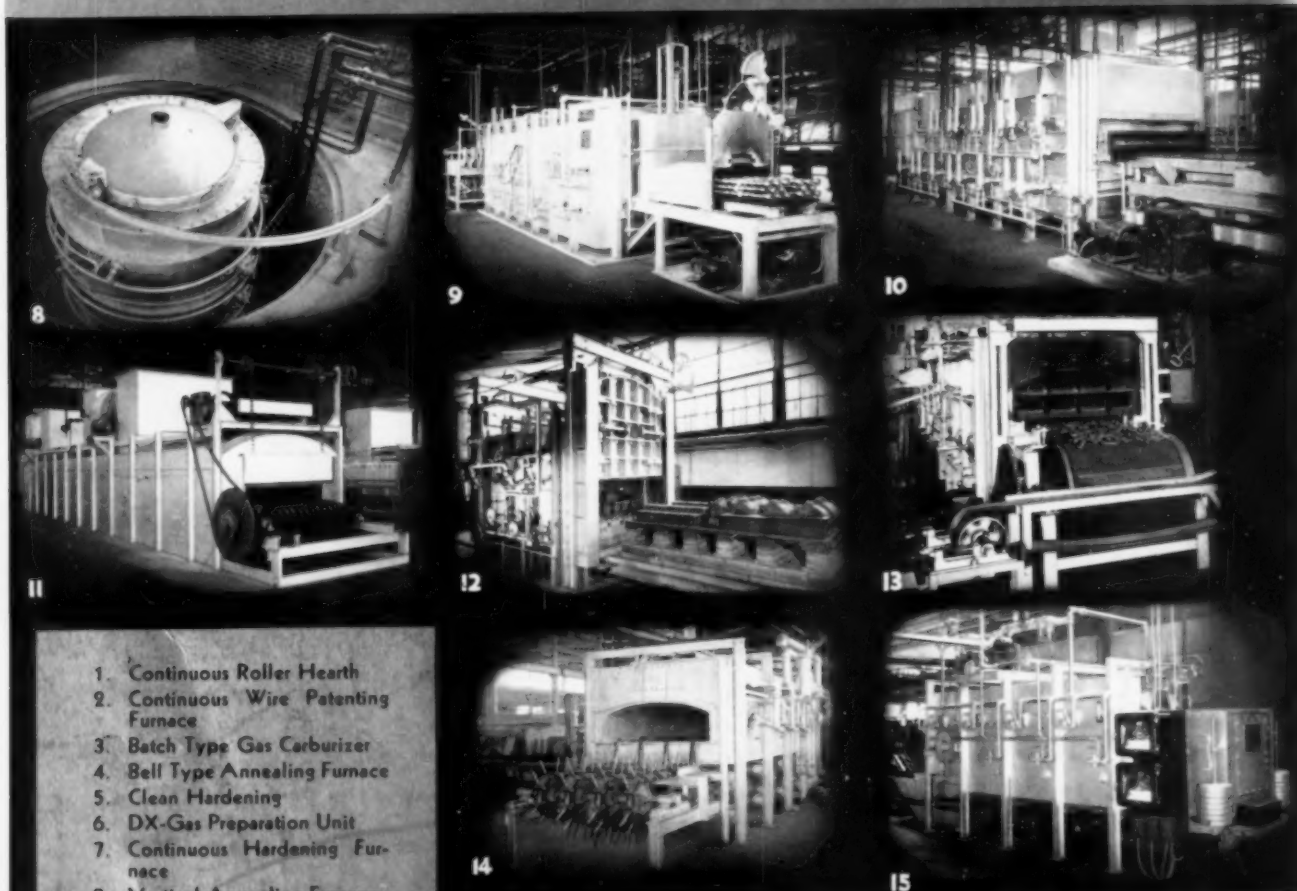
# PROGRESS

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American Society for Metals

# METAL PROGRESS

February, 1936, Vol. 29, No. 2

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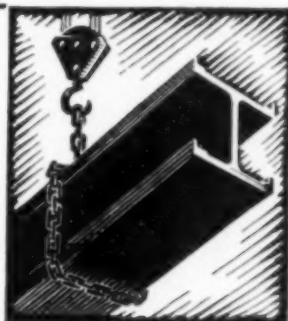
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# ACETYLENE

## Yesterday, Today, Tomorrow

**W**HILE THE ALUMINUM INDUSTRY DOES WELL TO celebrate the fiftieth anniversary of Hall's discovery — the basis of today's industry — the acetylene industry might equally well observe a centenary, for in 1836 Edmund Davy told the British Association about a new, un-named gas, undoubtedly acetylene. Its commercial possibilities lay latent, however, until 1892, when Thomas Willson and James Morehead produced calcium carbide in an electric furnace. There is more than an accidental connection of dates, for unwanted carbide was produced instead of calcium, which they wanted for a reducing agent to get aluminum from its oxide!

In less than a half-century calcium carbide and acetylene have formed the basis of many new industries. First in point of time came the use for lighting. An open flame of acetylene has the highest known candle power, and there will always be times and places where this unique property will be useful, but as a main branch of the industry, acetylene lighting (house lighting, miners' lamps, automobile truck and railroad car lights) is definitely on the wane, already relinquishing first place to welding.

That welding is the first interest of the carbide industry at present is proved by the programs of the International Acetylene Association. This interest is bound to grow, for welding as an industry is in its very infancy, and welded joints are so essentially correct that nothing else will be acceptable to future constructors (except in places where occasional unjointing is necessary). How else, for example, could a smooth, streamlined body for an automobile be fabricated?

But welding can be done in many ways, so the question arises as to whether other means of welding will eventually preempt the field. Automatic electric machinery seems now to be the most vigorous competitor, but for ability to handle work on all varieties of metals and alloys, the oxy-acetylene flame stands in first place. Likewise nothing is in view that can compete with the cutting flame; do not be surprised to find it taking more and more work away from high speed

steel tools on all sorts of rough machining cuts.

Even though cutting and welding now form No. 1 branch of the carbide industry, the chemical applications of acetylene have expanded with such surprising rapidity that the relative importance may quickly be changed. Carbide, as the basis of cyanamide and thence on to the fixation of nitrogen for fertilizer and nitric acid, formed the basis of a respectable industry even prior to the War. Another war-baby, carbon black, now requires about 5000 tons of carbide annually for acetylene black, having properties giving it especial value for dry batteries. Only in quite recent years, however, has the use of acetylene gas rather than solid calcium carbide achieved such large chemical importance.

Every high school student of chemistry knows that methane gas ( $\text{CH}_4$ ) is the starting point of a huge number of "aliphatic" compounds including paraffins, fats, oils and alcohols. Benzol ( $\text{C}_6\text{H}_6$ ) is the starting point of a second group of "aromatic" bodies including aniline and all the coal-tar derivatives. It now appears that by starting with acetylene ( $\text{C}_2\text{H}_2$ ) and working water into that highly unsaturated and active molecule, we get acetaldehyde, something easily oxidized into acetic acid. Here we have not only synthetic vinegar but an acid greatly needed in manufacture of various dyes, lacquer solvents, transparent paper and artificial silks. Perhaps 100,000,000 lb. of the gas is so used annually.

Theoretically, acetaldehyde can be the basis of fatty acids, glycerin, fats, alcohol, coal tar bodies, and gums. Practically, some of these products are even now commercial, notable recent developments being the vinyl resins (molded condensation products, plastics, beer-can lacquer, and safety "glass") and synthetic rubber.

Since the start is just being made, it is not a rash prophecy to say that the future field of first importance to the acetylene industry is the chemical. As one leading chemist puts it, "The problem of finding uses for the large and growing family of chemical compounds is far more pressing than that of their production."

## Contributions of

# ALUMINUM

## to Metallurgical Progress

**T**HE ALUMINUM INDUSTRY AND SCIENTIFIC WORKERS interested in aluminum have made substantial contributions to general metallurgical progress. These contributions have not only been of a practical nature, but have advanced our fundamental knowledge of metals and alloys. In addition, there is a regular "Horatio Alger Story" to be found in the early history of the aluminum industry.

First, The Story! It was no mere accident that led Charles Martin Hall to the discovery of a practical electrolytic process for the reduction of aluminum. If fortune smiled on him, it was because his reasoning was sound and his efforts untiring. Inspired by a passion for chemistry and chemical knowledge, Hall, during his Oberlin College days, kept thinking and experimenting on possible ways of producing aluminum. Was not every clay bank a mine of aluminum, and the metal as costly as silver?

In his first experiment, Hall tried to reduce aluminum from clay by means of carbon at high temperatures. The experiment was a failure. Aluminum was produced in those days by chemical reduction of sodium aluminum chloride with metallic sodium, and Hall speculated for a while on processes of producing cheaper aluminum chloride. But that was not his goal. Aluminum oxide was a relatively cheap and readily available compound of aluminum. Reduce it he must! He looked for a catalyst which would give him aluminum in a reaction with alumina, carbon, and other compounds such as barium salts, cryo-

lite and soda, but with negative results. These experiments were not without value, however, for gradually there was forming in his mind the analysis of his problem which was to lead him to a practical solution.

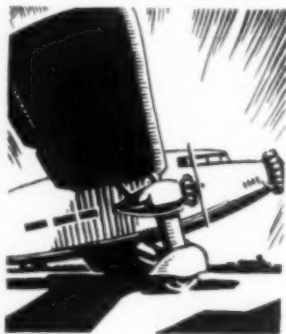
In Hall's own words — "I had studied something of thermochemistry, and gradually the idea formed itself in my mind that if I could get a solution of alumina in something which contained no water, and in a solvent which was chemically more stable than the alumina, this would probably give a bath from which aluminum could be obtained by electrolysis."

When he graduated from college, Hall began to experiment along these lines. He had no International Critical Tables or collection of handbooks to turn to for solubility data. In fact, no one then knew of a fused salt in which alumina was soluble, or even if such a combination was possible. Fluorspar (calcium fluoride) was the material he first tried, but its fusing point was too high for his equipment — and the solubility of alumina in it too low for his purpose, if he had only known it. Magnesium fluoride failed for the same reasons. It must have been some latent chemical instinct which led him to start his investigations among fluorides. Their fluxing characteristics were known, and perhaps this suggested applicability to his problem. For his third experiment he tried cryolite. He found it could be readily fused and in the molten condition it dissolved alumina freely.

The stage was now set for his discovery — and what a stage —

by  
**Junius D. Edwards**

Asst. Director of Research,  
Aluminum Research Laboratories,  
New Kensington, Pa.



the family woodshed! For equipment he had a small home-made furnace and bellows, a clay crucible, and a home-made battery for his current supply. He melted some cryolite, dissolved alumina in it, and passed current through the melt for about two hours, but found no aluminum in his crucible. This failure he thought might be attributed to silica and other impurities from the clay crucible. So he made a carbon crucible for the next experiment. This time, after several hours' electrolysis, he found a number of small globules of aluminum in the bottom of the crucible. This was February 23, 1886, just fifty years ago.

While Hall had discovered a practical process of making aluminum, commercial success was still some distance away. There were many technical details of the process which required investigation and development. Financial backing also had to be obtained to promote the process. To all of this, Hall applied himself with enthusiasm. After several discouraging episodes, he obtained the backing of a Pittsburgh group headed by Alfred E. Hunt. The Pittsburgh Reduction Co. (now Aluminum Company of America) was launched in September, 1888, and production of aluminum started in November of the same year.

As a semi-precious metal worth many dollars a pound, aluminum seemed to be a most sought-after metal; when available for less than a dollar a pound, there was no rush to buy it. Little was known regarding its applications in the industrial arts, and it was necessary to start a long program of investigation and education. The properties of the metal had to be determined, fabricating technique developed, new alloys of adequate strength and ductility discovered, and all of these new facts brought to the attention of a conservative metal-using public, reluctant to pioneer. The story has been told many times, but the program of research and

education has by no means yet reached an end.

Hall, in his electrolytic reduction of the oxide, achieved something quite novel. The electrolytic reduction of metals from fused salts was not new in principle. In fact efforts, not commercially successful, had been made to produce aluminum by the electrolytic reduction of sodium aluminum chloride. Other difficultly-reducible metals had been produced by the electrolytic decomposition of some fused compound, usually

the chloride. Hall hit upon the unique plan, however, of electrolytically decomposing the relatively cheap oxide while it was dissolved in a stable bath of fused fluorides. It was a fortunate circumstance that his electrolyte was lighter than aluminum, so that the metal would sink through the bath and be protected thereby.

The oxide may be electrolyzed smoothly and at low voltage from the cryolite bath. Cryolite is a sodium aluminum fluoride, and can be decomposed only at substantially higher voltages and to the running accompaniment of the so-called anode effect, which makes it impractical commercially to secure aluminum from the fluoride. Even today, aluminum is the only metal which is electrolytically produced



*Charles Martin Hall, 50 Years Ago,  
Invented the Electrolytic Process of  
Producing Aluminum From Its Oxide*

from its oxide. (Although magnesium has been produced commercially from the oxide suspended and dissolved in a fused fluoride bath, it as well as calcium, cerium, lithium, and sodium, are all now produced by the electrolysis of the metal chlorides.)

Just in passing it may be remarked that it was the desire to supply the world with cheap aluminum that led Hamilton Y. Castner to invent a process for producing sodium electrolytically. Sodium, at that time, was being employed for the chemical reduction of aluminum from sodium aluminum chloride. It was Castner's misfortune that the technical success he achieved in producing sodium was of no interest to the aluminum industry, reborn with the Hall process.



Making aluminum available at a low price was in itself a notable contribution to metallurgical progress. Aluminum, with its low density, good electrical and thermal conductivity, resistance to corrosion, and structural strength in alloy form, has become an indispensable member of the family of metals. In reaching this position it has made important contributions in other fields of metallurgy.

The difficulty early chemists had in reducing aluminum from its oxide is partly explained by the high heat of formation of this compound. This avidity for oxygen has enabled it to perform for many years an important task for the steel industry. Reduction of the oxides in steel is a task for a potent oxygen absorber, and metallic aluminum does the job well. Although the pic-

ture has been confused at times, it is now becoming increasingly clear that aluminum has a permanent and important place in the production of sound steel ingots, and in the control of grain size. As an alloying ingredient in steel, aluminum has been almost neglected, but future years may see important changes in this field of application.

This avidity for oxygen has enabled aluminum to perform other difficult metallurgical tasks. The thermit process of reducing metal oxides with metallic aluminum is well known and described in almost every high school text on chemistry. Difficultly-reducible metals, such as titanium, vanadium, and manganese, were made available in this way for the first time at a reasonable price. Although metallurgical prog-



*The Smithfield Street Bridge, Pittsburgh, Being Reconstructed With a Strong Aluminum Alloy Floor System. The 8-in. aluminum cambered channel the man is carrying is 21 ft. long*

ness has now found cheaper ways of reducing some of these metals, the contribution of aluminum remains an important one.

The welds produced by superheated steel from the thermit reaction were most excellent. Even though gas and electric welding have largely occupied this field, the excellent character of the thermit welds in heavy members undoubtedly promoted confidence in welded joints of all kinds, and stimulated the development of still better welding methods.

In the domain of theory, aluminum has also been a contributor. When Alfred Wilm, about 1907, discovered the wrought alloy duralumin, he provided a new metallurgical mystery for scientific sleuths. Here was a wrought material which could be heated and quenched with some improvement in properties, but which subsequently experienced a very important change just on standing at room temperature. During a period of about four days after heating and quenching, there is a 50% increase in tensile strength without any loss in ductility. During the World War this new material found many uses, particularly in the field of aviation; but there was little time for anyone to investigate the mystery of its behavior. However, the scientific curiosities of Paul D. Merica and his associates at the National Bureau of Standards were aroused when studying the heat treatment of duralumin, and their investigations led them to an adequate explanation of the phenomenon.

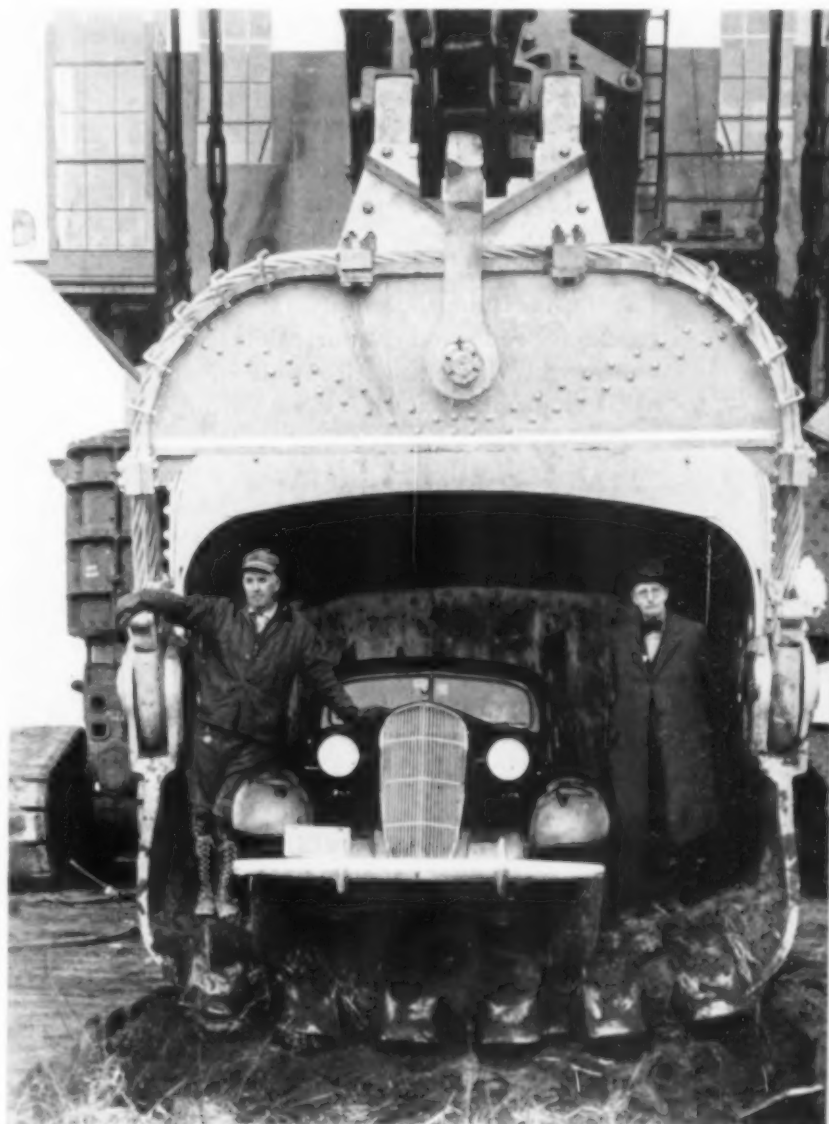
An exact investigation of the behavior of duralumin on heating and cooling showed discontinuities in the curves, which Merica, Waltenberg and Scott rightfully attributed to the precipitation from a supersaturated solution, of some constituent dissolved during the high-temperature treatment preceding quenching. On the basis of their investigations, they advanced the hypothesis that the copper in duralumin was substantially all dissolved in the solid aluminum by the heating at temperatures around 950° F. The solid solution thus formed was preserved at room temperature by the quenching of the alloy. Because of the decrease in solubility of the dissolved constituent at the lower temperature, the solid solution was supersaturated and unstable after cooling, and the excess constituent precipitated slowly in highly dispersed form, even at room temperature, thus giving the natural aging phenomenon which was so mysterious when first discovered. The new and bold conclusion was advanced that the solid solution containing the highly dispersed precipitate was

harder and stronger than the solid solution itself. The process is frequently termed precipitation hardening, or if the emphasis is on the last step, it is termed age hardening.

The theory they developed was a notable contribution, for it suggested that duralumin was probably not the only alloy that would exhibit precipitation hardening, but represented a great class of alloys, hitherto unsuspected and unpromoted. This turned out to be the case. Not only were other very useful heat-treatable aluminum alloys discovered, but alloys of other metals were found that exhibited similar behavior on heating, quenching and aging.

The slip interference theory of hardening, so ably advanced by Jeffries and Archer, has given us a satisfying picture of just why the pre-

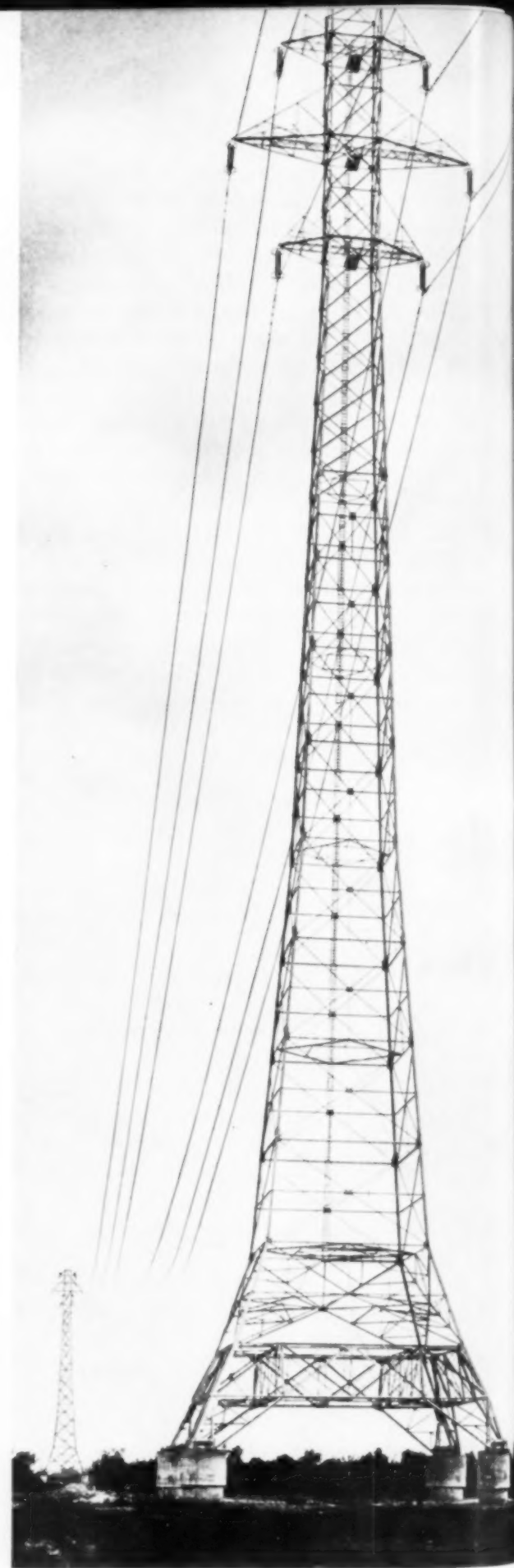
*Largest Shovel-Dipper Ever Built Holds 32 Cu. Yd. Overturning moment largely reduced by extensive use of strong aluminum alloys, thus reducing the weight*



cipitation of finely dispersed particles of constituent from solid solution should cause increased strength and hardness. According to this theory, the numerous sub-microscopic particles of some constituent, dispersed throughout the crystal lattice, act as locks or keys on the crystal slip planes. The resistance to slip thus conferred gives the alloy increased strength and hardness.

As an example of the type of difficulties aluminum met in its introduction to the industrial world, mention may be made of its use in electrical conductors. Prof. Joseph Richards, Chronicler of The Aluminum Industry, writing in 1890, said: "It (aluminum) has been suggested, if it ever becomes cheap enough, as a material for telegraph wires, for which its high conductivity would fit it, but it is no stronger than copper and not nearly so good a conductor, so that it is not likely that this use will ever be made of it." It was indeed soon found that the physical properties of the commercially pure metal were not adequate for transmission line construction, so an alloy was tried. This alloy, aluminum with 2% copper, soon began to fail from corrosion. At this juncture the late William Hoopes, then chief electrical engineer of Aluminum Co. of America, conceived the idea of an aluminum cable for conductivity, with a steel core for strength. Aluminum cable, steel reinforced, met all requirements, and to date over 430,000 miles of this cable have been installed in the United States. But it has required constant effort to reach this stage. The supplier of cable has had to make a fundamental study of transmission line construction in addition to supplying the conductor. As just one item, reference may be made to cable vibration. Gentle winds may start a cable vibrating, and vibration of sufficient amplitude will eventually cause fatigue failure of cable and fittings. A fundamental study of the problem in the laboratory and in the field provided a practical solution to the problem in the form of vibration dampeners. The information gained in these studies will be of practical value in other fields.

William Hoopes' versatile mind contributed in many other ways to the aluminum industry. Notable among them was the Hoopes electrolytic refining process for producing pure aluminum. In the Hall process, any impurities in the alumina or electrolyte, such as iron or silicon, are reduced and appear in the aluminum; purity therefore depends on the purity of the raw materials entering the reduction cell. No practical means of refining commercial aluminum was available. The Hoopes process is unique among metallurgical operations, in that it operates with a molten anode and cathode separated by a layer of molten electrolyte. The anode layer, a heavy aluminum-copper alloy, rests on the bottom of a carbon-lined cell. Floating on the anode is a layer of fused fluoride electrolyte, and on top and lighter than the electrolyte is a layer of pure aluminum acting as



*Aluminum Cable, Steel Reinforced, Has Definite Advantages for High Voltage Electrical Transmission. Advantages Utilized to the Utmost in This Long Span Crossing the Mississippi River*



cathode. Pure aluminum, electrolytically dissolved from the anode, is deposited in the cathode layer to which current is led through graphite electrodes. Aluminum of 99.99% purity has been made in this way.

Entirely apart from its commercial applications, this metal of very high purity provided material for determining the properties of the pure metal for the first time. E. H. Dix, Jr. and his associates, working with Hoopes' refined metal, have established the equilibrium diagrams for the aluminum alloy systems of most interest. These investigations, carried out with the most precise methods available, have constituted an important contribution to our fundamental knowledge of metals. They have also proven invaluable in the development of aluminum alloys to meet the varied demands of modern industry.

Alclad products, with an aluminum alloy core integral with a pure aluminum coating, have proven their merit from the start. The discovery that the pure metal coating offered electrolytic protection to an aluminum-copper alloy core has many practical applications. Working along these lines, a number of very useful core-and-coating combinations have been developed.

### Structural Aluminum

Reference has been made to the repeated necessity in the progress of the aluminum industry, of not only supplying the metal, but teaching the customer how to use it. The structural applications of aluminum in transportation, such as aircraft, automobiles, trucks, and railway cars, as well as in booms and bridges, have led to a fundamental study of structural design for lightness and strength. R. L. Templin and the group working with him have made important contributions in this field and are placing aluminum in many new structural fields. Again, these investigations—fundamental in nature—will increase the efficiency of application of other metals, and hence contribute to general progress.

With all the advances of 50 years, since the Hall process made aluminum an inexpensive metal, there is still much to be accomplished in increasing its serviceability to mankind. The enthusiastic hopes of Hall and other pioneers for the coming of an "Aluminum Age" are still but dreams. In the meantime, constant research—both scientific and technologic—is making of aluminum a very useful member of the family of metals.

# NITRIDING OF AUSTENITIC STEELS

By Brynmor Jones

*Condensed from Carnegie Scholarship Memoirs  
British Iron & Steel Institute*

**A**LTHOUGH THE PRESENT AUTHOR HAD ALREADY investigated the nitriding characteristics of some high alloy steels at 950° F. for 90 hr., a new series of experiments, 48 hr. duration, was undertaken to find the depth of hardening and optimum nitriding temperature for austenitic manganese, chromium and nickel steels.

Of the series of high manganese steels, the greatest hardening occurred at 1035° F. in a steel containing 18.4% Mn and 0.15% C. Its hardness was 1000 Vickers Brinell (diamond cone) about 0.001 in. below the surface; half the added hardness was lost at a penetration of 0.004 in. After nitriding, the steel was found to be slightly magnetic, although the core remained non-magnetic. This was due to decomposition of austenite of marginal layers into  $\alpha$ -iron and nitrides.

An austenitic nickel steel (34.7% Ni) could not be hardened in this series of experiments. A nickel-manganese steel (14.6% Ni, 4.9% Mn, 0.46% C) did not harden appreciably until at temperatures of 1125° F., and then only mildly to 465 Vickers Brinell.

In a rust resisting martensitic steel containing 13.3% chromium and 0.35% carbon a surface hardness of 1000 Vickers Brinell or over was obtained by nitriding 48 hr. at several temperatures between 850 and 1035° F.; best penetration (0.009 in. to half the added hardness) occurred at 1035° F. Higher temperatures lowered the surface hardness progressively.

Another martensitic stainless steel containing 17.8% Cr, 1.7% Ni, and 0.14% C gave a surface hardness greater than 900 when nitrided 48 hr. at all temperatures between 950 and 1200° F. Within this range an increased temperature of nitriding resulted in the production of a greater depth of case without the loss of much surface hardness. Two-stage nitriding, 24 hr. at 950° F. and 24 hr. at 1125° F., gave a surface hardness of 1150 and a total depth of case of 0.010 in.

Microstructures of the cases on these two steels are similar. The diffusion of nitrogen into the marginal layers of the steels gives rise to the formation of many insoluble particles of chromium nitrides. The depletion of chromium in the matrix destroys the (Continued on page 72)

**Durability of**

# PLATED STEEL

**Exposed to Weather**

**D**URING THE PAST SEVERAL YEARS THE AMERICAN Electroplaters' Society, the American Society for Testing Materials, and the National Bureau of Standards have cooperated in extensive tests on the protective value of plated coatings on steel. The results obtained with nickel and chromium coatings have been published in Research Papers No. 712 and 724 of the Bureau of Standards under authorship of P. W. C. Strausser, A. Brenner and W. Blum, and a paper on the zinc and cadmium coatings will be published in the near future.

*Exposure Tests.* The plating was applied to pieces of cold rolled steel, each 1x6 in. Five specimens each from about 120 sets were exposed to the weather continuously in six locations, namely Key West, Fla.; New York; Pittsburgh; Sandy Hook, N. J.; State College, Pa.; and Washington, D. C. The type of test rack is shown in the halftone, being the result of years of experience by other A.S.T.M. committees. They were inspected at intervals by a joint committee, who assigned numerical ratings based upon the proportion of the surface which rusted.

The results showed that the total thickness of nickel, or of nickel plus copper, is the most important factor in the protective value, and that in severe exposures an average thickness of at least 0.001 in. is required to give good protection. The presence of a copper layer in thin composite coatings is detrimental, but in thick coatings the copper is harmless, especially if chromium is finally applied. The usual chromium

coatings with a thickness of about 0.00002 in. add very little to the protection against corrosion, and are chiefly valuable for resisting tarnish.

Thin coatings of either zinc or cadmium furnish better protection against corrosion than do equally thin coatings of nickel or chromium, though they rapidly lose their luster. In purely marine or rural climates as little as 0.0002 in. of zinc or cadmium furnishes protection for a few years. In industrial exposures, where sulphurous acid is present, such coatings fail within a year, and the cadmium furnishes only about two-thirds as much protection as an equal thickness of zinc.

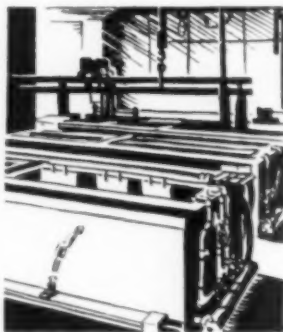
Conditions used in these experiments for depositing the zinc or cadmium had no marked effects on their protective value. Hot-dipped zinc coatings gave about the same protection as plated zinc coatings of the same thickness.

*Accelerated Tests.* As the protective value of quasi-noble metal coatings, such as of copper, nickel and chromium, depends principally upon their freedom from porosity, a simple test for porosity (for instance the ferroxy test) is very useful, especially for factory inspection. (See also the distilled water test for tin coatings described on page 39 of last month's METAL PROGRESS.) The salt spray and intermittent immersion tests also detect pores but require a longer period. Their results are only roughly parallel to results of atmospheric tests.

As the protective value of coatings of zinc and cadmium (in contradistinction to coatings of copper, nickel and chromium) depends

**By William Blum**

Chemist  
Bureau of Standards  
Washington, D. C.



Summary of address before various A. S. M. Chapters. . . . Publication approved by Director, Bureau of Standards

principally upon their thickness, accelerated corrosion tests are of value only to the extent that the results are proportional to the thickness. This is approximately true for zinc in a salt spray test, but not for cadmium. Coatings of the latter resist the salt spray for long periods, which have no direct relation to their value in an industrial atmosphere.

**Thickness Measurements.** The average thickness of any metal coating can be determined by stripping—that is, dissolving the coating from a known area, and determining its weight from the loss in weight or by chemical analysis of the resultant solution. Such methods have thus far been most extensively used.

Investigators have recently laid stress on minimum thickness, rather than average thickness as the controlling factor. This makes it desirable to determine the local thickness of a coating at any desired point. Metallographic examination of cross-sections is generally applicable for this purpose, but is troublesome and expensive. A "dropping" method recently described by Hull and Strausser in *Monthly Review of American Electroplaters' Society* for March, 1935, is applicable to zinc and cadmium coatings. This depends on measuring the time required for a specified reagent to just expose the base metal when it drops onto the coating at a definite rate.

Promising results have been obtained for both hard and soft metals by F. C. Mesle's "chord method" described briefly last year in *Metal Industry*, and upon which a more detailed paper is in preparation. This method depends upon measuring the width of the cut when the base metal is

just exposed by cutting through the coating on a plane surface with a grinding wheel, or with a flat file on a surface of known curvature.

**Specifications.** On the basis of the above results and of industrial experience, a joint committee prepared specifications for plating on steel that have recently been adopted by the American Society for Testing Materials and the American Electroplaters' Society as A.S.T.M. tentative standards A164-35T, A165-35T, and A166-35T. The essential requirements are as follows:

#### **Zinc or Cadmium**

- (a) For General Service: On significant surfaces, a minimum thickness of 0.0005 in.
- (b) For Mild Service: On significant surfaces, a minimum thickness of 0.00015 in.

#### **Nickel and Chromium**

- (a) For General Service: On significant surfaces the minimum thickness of copper plus nickel of 0.00075 in., of which final nickel is at least 0.0004 in., and average thickness of chromium, if required, 0.00002 in. The plate should withstand 48 hr. continuous salt spray.

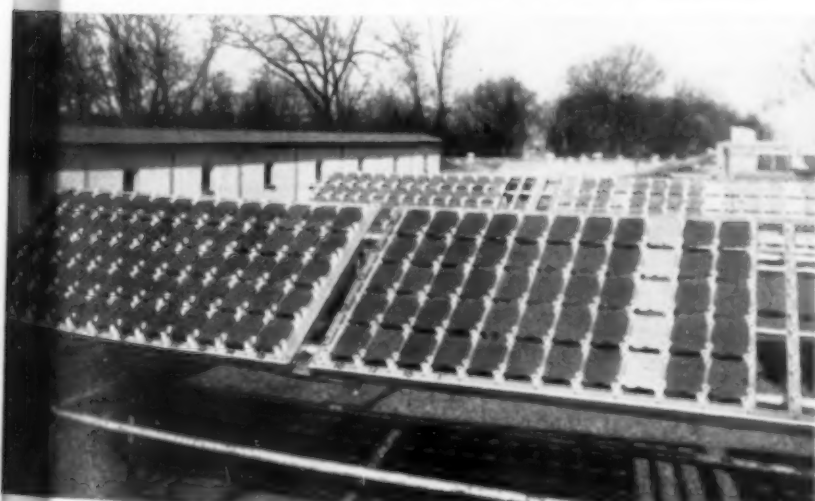
- (b) For Mild Service: On significant surfaces the minimum thickness of copper plus nickel of 0.0004 in., of which at least half is nickel, and average thickness chromium, if required, 0.00002 in. The plate should withstand salt spray 16 hr.

It should be noted that (except for chromium), these specifications define the *minimum* thickness on "significant surfaces", and that a considerably greater *average* thickness may be required, depending upon the shape. The salt spray test is conducted at 95° F.  $\pm 5^\circ$  F. (35° C.  $\pm 3^\circ$  C.), and failure is defined in terms of the number and size of the rust spots per unit area.

**Plating on Non-Ferrous Metals.** At present a large number of specimens of copper, brass, nickel-brass, zinc and die castings are being plated for similar exposure tests. A few sets of steel and cast iron will be included for comparison and correlation. It is hoped to start these exposure tests in the spring of 1936, after which laboratory studies will be made on companion specimens.

The above project illustrates the advantage of cooperation in investigations of broad public interest. Such cooperation has expedited not only the completion of the program, but also the practical application of the results.

*Racks Used for Exposure Tests of Electroplated Coatings at Washington. The specimens are held between porcelain knobs and face south at an angle of 30° from horizontal. Similar racks were used in other locations*





*Entrance to McGraw-Hill Building (Hood, Godley and Fouilhoux, Architects) Is Sheathed With Painted Steel and Colored Aluminum Sheet; Stainless Steel and Bronze Tubing Lead the Eye Toward the Entrance. Cleaning is a problem on such exposed metal*



*Photo by S. H. Gottschu*

## Metal in Functional

# ARCHITECTURE

### —Its Proponents' Views

**S**O MUCH HAS BEEN WRITTEN AND SAID OF LATE years about the architectural use of metals that the metallurgist may wonder why the architect has been so slow to utilize this, that or the other new alloy in a large way. A statement of the architects' position, as developed by a number of interviews with prominent members of the profession may therefore be illuminating to readers of METAL PROGRESS.

Every material employed by an architect must stand two tests, first, its ability to function adequately and reliably, and second, its ability to satisfy the eye of the observer. This duality does not contradict the basic principle of functional architecture, so-called — namely, that that structure which most completely and appropriately fulfills the requirements of the building program is the *best* solution of the problem. The architect finds at his disposal a large number of materials and methods, each equally capable of fulfilling the first test of reliability, and it is by his selection of the one most able to fulfill the second test (eye appeal) that he shows capability as a designer.

The largest part of a finished building never meets the eye. In selecting the materials for such portions, the question of appearance is totally absent, and the architect may proceed as an engineer rather than as a designer, and pay first attention to utility. But when he deals with the *visible* portions, the ruling considerations divide into two categories, (a) those where utility is paramount and (b) those where appearance is of first importance. Here again the ability of the architect is tested, for exposed utilita-

rian form which is decorated is poor design — as poor design as a plain ornament.

Through the long history of architecture, metal as a building material has been confined with rare exception to the second of the above classifications — that of decoration. The masterpieces of the classic period were constructed of stone or of concrete, and the more rare and stubborn material, metal, was utilized only for dowel pins between massive blocks, or for door coverings and bindings. Not until centuries later were copper and lead sheet used on roofs. That was about the limit of utility until within the last 100 years cast iron and steel became available for beams, columns and trusses. So it is apparent that an extensive architectural use of metal in a utilitarian way is a very recent innovation, as the centuries go.

For decorative purposes the Greeks and Romans cast many bronze statues and reliefs, tripods, urns, and shields, and from medieval times on, notable iron and bronze work, both cast and wrought, adorned many architectural creations throughout the world. A fairly generous supply of easily fusible metal and the development of intricate forging and foundry methods make metal decoration one of the commonest of styles. This persists even today, as can be proven by a visit to the Metal Products Exhibit at Rockefeller Center, New York, where most of the examples of architectural uses of various metals run to elaborate decorative treatment of entrances and foyers.

However, some very successful results of the interior use of metal from

As told to  
**F. Charles Thum**  
Princeton, N. J.



a utilitarian standpoint have been attained in such examples as the Inquiry Bureau of the Metropolitan Life Building in New York City by the architects Waid and Corbett. As shown in the view below, an atmosphere of extreme practicality and efficiency is achieved by emphasizing the surface of the painted steel partitions; its only ornament is attained by allowing the joints between vertical and horizontal members to be clearly visible, as well as the transition from the upright posts (made of 14-gage steel) to the adjustable floor sockets made of nickel bronze. The only non-functional decoration (that is, decoration not logically derived from the structural or utilitarian requirement of the decorated object) is reserved for the cornice with its dentils and moldings and the coffering of the ceiling. Even the pattern on the ceiling surface is the result of joining the acoustic tiles. These tiles consist of perforated steel pans, having a baked enamel finish, which hold acoustical pads.

Stair railing, ceiling fixtures, and partition floor sockets are of a white nickel bronze containing 13% nickel in the extruded shapes, 15% nickel in all sheets and tubes, and 16% nickel in

*Interior Use of Metal for Its Strict Utility Exemplified by Inquiry Bureau of Metropolitan Life Building (Waid and Corbett, Architects). White nickel bronze extruded shapes and castings, enameled steel partitions, ceiling and furniture*

*Photo by Sigurd Fischer*



the castings. All the steel is finished with a baked enamel of a color blending with this nickel-copper alloy. These booths show clearly how an architect, working upon basic principles of functionalism, can satisfactorily solve a problem falling under the heading of strict utility without calling upon decorative forms to appease the eye, and how he can express a material by its form alone, even though its color and texture are destroyed by painting the surface.

### Sheet Metal for Exteriors

This is again seen in the Rex Cole Show Room in Brooklyn, work of the architects Murchison and Hood, Godley and Fouilhoux, illustrated on the opposite page. Here all walls are sheathed in welded and painted sheet steel. Although painted bands of color and printing add to the decoration, the essential masses of the building—leading up to the enormous refrigerator—are the fundamental means of attracting the eye. The nature of the corners, the identity of the planes of the walls and windows, the visible welded joints, and the minimizing of moldings all clearly show that the building is executed in sheet metal. This building indicates the remarkable and unusual effects at the disposal of the builder in metal.

However, Mr. Fouilhoux's experience has been that this material is, as yet, no more economical than any of the commoner and more bulky materials, as the saving in raw material is eaten up by the expenses of obtaining workers experienced in handling it or in training the inexperienced. Metal is also at a disadvantage in competition with older building materials which are available in a satisfactory range of stock sizes, developed by long experience with them in construction. For exposed wall surfaces the architect needs an equivalent set of small metal units which he can fit together to form his own designs for the sheathing necessary to cover the steel skeleton (which has been so thoroughly developed and so useful). Stock wall sections already supplied with various openings, or even stock parts such as doors and windows, are not acceptable to the individualistic architect, in Mr. Fouilhoux's opinion.

Turning now to the consideration of examples where the decorative purposes of the design are more important than their utility, the problem becomes more difficult if it is to be solved in metal. This is due to the fact that the architect, recognizing in the color, texture, and possibilities





*Exterior Use of Metal for Its Strict Utility Exemplified by Rex Cole Show Room (Murchison and Hood, Godley and Foulhoux, Architects). Welded joints in sheet steel are left exposed and even accentuated by painted bands of color*

of polish of the metals a means of attracting and pleasing the eye (which is the purpose of all decoration) desires to leave the metal surface exposed to view, but finds that it will not retain its original appearance, that it tarnishes and requires constant cleaning. In interior use, as in the example given above of the Metropolitan Life Building, or in the elevator lobby of the McGraw-Hill building in New York by Architects Hood, Godley and Foulhoux, the problem of cleaning is relatively simple, because of the cleanness of the conditioned air, and the smooth surface facilitates rather than hinders the cleaning. Moreover, in the average interior no metal is far beyond the reach of the polishers, and short step-ladders or mops on poles reach every part.

The exterior problem solved as shown in the view on page 42 is very difficult. Here the steel sheets between the windows (and the window frames themselves) have been painted; the wide bands of the frieze and door treatment are colored aluminum. Where stainless steel and bronze tubing have been used they have been covered with transparent varnish. All this is frequently cleaned. The magnificent lettering is bronze and glass enamel on bronze, but it collects dirt rapidly and is very difficult to clean without obstructing the entrance.

The treatment with tubing at the door is most effective and useful, architecturally, to draw the observer's eye to the entrance by this series of brilliant lines running from the plane of the facade around the corner and leading into the doors. Yet the problem of upkeep makes it questionable whether the architectural advantages outweigh the economical disadvantages.

#### **Maintenance of Brilliant Metal**

The front cover of the magazine shows an elaborate grille above the entrance to the Bonwit Teller building in New York by Ely Jacques Kahn; in it the difficulty of cleaning is all too obvious. This is made of stainless steel, a medium which in Mr. Kahn's opinion answers the architectural problem up to the time the building is completed. It is adaptable to small sections, thus allowing plenty of light through the window; its color is beautiful; it is possible to construct with it something of sufficient decorative beauty to draw attention to the entrance. Yet after completion of the building and removal of any builder's refuse, the dirt and foggy condensate from city air accumulates and dulls its luster rapidly; immediately the expense and inconvenience of cleaning begin.

To a metallurgist this might be an indictment of the atmosphere rather than of the metal, but the architect must build in congested and industrial areas, and his materials must conform to the surroundings rather than vice versa. Even if the metal is coated with a transparent varnish to protect the surface, the action of the atmosphere gradually gives the colorless varnish a slightly yellow tint. However, this procedure is the most satisfactory so far found for bright steel close to the street level, and the 18-8 so treated is most attractive. Mr. Kahn has adopted this solution to the entrance doors to the Yardley Shops in Radio City to the satisfaction of both architect and client. Of course, even in such cases, frequent washing of transparent or bright reflective surfaces is necessary.

The fact still remains, however, that a truly dirt-proof metal for exterior use in congested areas has not been found as yet by the architects interviewed. The vertical metal strips running up the pilasters between windows of the Empire State Building show clearly the action of the city atmosphere both by the slight dullness of color and by the black and streaked stains or deposits at the horizontal jointures of the metal. This is not altogether detrimental, as a matter of fact, for it has rather heightened the effect, as in this unique example the metal has been treated so broadly and placed so far above the eye of the observer that the luster is quite apparent and the loss in subtlety of surface texture is not noticeable from the street level. Furthermore, the dark deposits at the joints serve to emphasize the type of material used, by showing clearly the method of joining.

The consensus of these leading American architects is, then, that although the possibilities for the new and broader use of metal are many and varied, the absence of thoroughly adaptable unit sections hampers its use as a major building material and its inability to reflect its luster and finish when subject to the attacks of city air prevents the extensive use of various metals for exteriors. High cost also limits it to the more pretentious structures. Painted steel and exposed non-ferrous metals used for interiors have proved highly satisfactory but there is still something to be done before exposed metal on the outside will prove satisfactory to both architect and owner. It should be emphasized that the above has not considered in any way the possibilities of more extensive use of metal in the skeleton or frame of buildings smaller than the multi-story and industrial buildings in which its value is preeminent.

## COPPER HOUSES

By E. J. Malvey  
New York

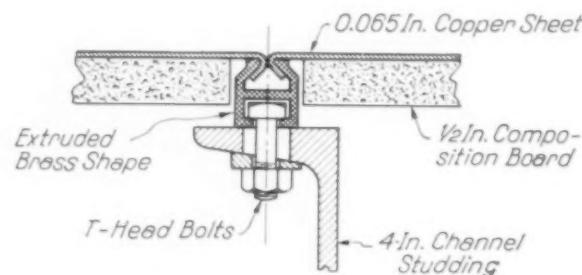
WHILE COPPER HOUSES HAVE BEEN BUILT IN European countries, they have been designed in extremely modern style, much too radical to attract the American owner. Consequently the first one in this country was made on quite conventional lines. It was recently completed in Bethesda, a suburb of Washington, by Copper Houses, Inc., subsidiary to Kennecott Copper Co.

This first copper house is of the British farmhouse type, although plans are prepared for a number of houses in styles of architecture harmonizing with the finer type of American residences. Many savings of the pre-fabricated idea are embodied in their construction without sacrificing the beauty associated with older forms of construction in timber, brick and stone.

The building has a structural steel frame for its first floor. Vertical members (studs) are 4-in. steel channels, set 32 in. on centers and adequately crossbraced. Floor joists for both ground and second floor are supported by this steel, and being 12-in. trussed steel beams, need no intermediate supports. Interior partitions may be placed at will, and in fact changed from time to time to suit the needs of the occupants, just as may be done in a modern office building. Also the various service lines can be threaded through the joists to reach any desired location.

Outside walls up to the eaves are built of copper sheets, 0.065 in. thick, weighing about 3 lb. per sq.ft. The vertical edges of each sheet are flanged over to fit within an extruded brass shape, which in turn is bolted to the studs by T-bolts. The construction is shown in the sketch, which also shows a half-inch layer of composition board cemented to the copper plate for insulation and stability and to dampen the effect of any sounds.

(Continued on page 88)



Detail Showing Attachment of Copper Sheathing to Steel Studding by Means of Extruded Shape

**Sheet Metal Base for**

# **BATH TUBS**

**Competes With Cast Iron**

**E**NAMELED SANITARY WARE USING SHEET METAL instead of an iron casting for a foundation appeared on the market in 1932. In that year the first completely satisfactory lavatory made of formed metal was ready for the market. Once the ice was broken, experiments were conducted with allied products. The lavatory was followed by the successful forming and enameling of bathtubs, kitchen sinks, laundry tubs and cabinets, and experience with this variety of plumbing ware has since proven its entire reliability.

While the use of formed sheet iron in the mass production of sanitary ware is revolutionary in character, it is along the lines followed by many industries in recent years. The goal of manufacturers has been to eliminate unnecessary weight, increase strength, improve appearance and quality of products and reduce costs of shipping, handling and installation—all major factors that help to lower the ultimate cost to the consumer.

The fundamental differences involved may best be appreciated by a few remarks about the manufacturing processes. Cast iron for enameling purposes has very special characteristics; it must be sufficiently fluid to cast into very thin walls, yet without blowholes, porosity or slag spots. Its coefficient of expansion must be right and the enamel adjusted thereto. Perfect castings are absolutely essential. Design is also important; the parts must have rounded corners and edges, so cast that they will have every opportunity to heat uniformly in the enameling furnace. If one part is fired more speedily than another, there may be defects in the enamel and a resultant unsatisfactory appearance.

It is equally true that a good

base of sheet iron is absolutely fundamental to successful enameling. Considerable research was necessary before a special quality of Armco iron was developed, capable at once of deep forming into intricate designs, bonding securely with porcelain enamel, and free from elements which produce "blisters" and "fish-scales" in the enameling during firing. It was then found that a 14-gage sheet of this special smooth, velvety finish (not a spongy surface but firm and fine grained) will be stiff enough and bond strongly enough to the porcelain so the latter will not chip or crack unless the ware is grossly mistreated.

Obviously the equipment and methods necessary for forming and pressing the sheet metal in shape between appropriate dies are quite different from foundry methods on cast iron. There are definite differences also in the finishing operations.

Sand blasting is the most satisfactory method of cleaning and preparing a cast iron surface for an enamel finish. The rough edges, gates and molding sand are first removed. A thoroughly cleaned surface is one of the first requirements for good enameling.

After the wet ground or slush coat is applied, the casting is fired in a furnace heated to 1350 to 1400° F., removed from the furnace and a coat of powdered enamel is sprinkled on the hot surface through a sieve. The casting is immediately returned to the furnace, and the process is repeated until the entire surface is smooth and free of defects. Sometimes the enamel on cast iron reaches  $\frac{1}{8}$  in. thick in certain areas.

Sheet metal products, on the other hand, are prepared for enameling by pickling. The formed sheets are first submerged in an

**By Bennett Chapple**

Vice-President

American Rolling Mill Co.

Middletown, Ohio



alkaline cleaning solution to remove any oil or grease, then they are rinsed in water. After an acid pickling they are rinsed again and then sent through a neutralizing solution. After the sheets have been thoroughly dried they are ready for the first coat of enamel.

Sheet iron is given a special ground coat to secure the strongest bond with the metal surface, and to serve as a base for the finish coats. The ground coat most commonly used is a composition of feldspar, borax and quartz, with smaller quantities of soda ash and niter, cobalt oxide and manganese dioxide. The latter oxides are termed "adherence oxides" because they promote the intermingling of glass and metal, giving intimate contact that resists stress and strain. They also give it its name, cobalt blue, from the characteristic color.

When the ground coat has been applied to the formed metal by dipping in or spraying on the blue composition, it is taken to a large furnace and fired from 3 to 7 min. at 1580 to 1600° F. After cooling and inspection, the first white, or cover coat, is sprayed on the product, and it is again fired in a furnace at approximately 1560° F. The process is repeated for successive coats, ending with the acid resisting coat which is standard on the new formed metal plumbing ware.

Decorative effects are obtained by applying color with a soft composition roll. This enamel is fired at a lower temperature than is required for the enamel base; the decorations, however, are thoroughly fused into the enameled surface. There is no limit to the use of color or color combinations when using the wet process on sheet metal. Intricate designs can be reproduced with perfect results. As a consequence, products in a varied range of colors have been placed on the market.

Another feature of importance is that the enameling of tubs formed of sheet iron paves the way to a safer bath. The base of the new tub has been embossed with shallow, wavy corrugations for a non-skid tread. This feature should have a definite appeal as accident insurance companies are not entirely happy over the claims for injuries on slippery floors.

One of the most striking differences is in the weight of the two products. To illustrate, a cast iron bathtub, 5 ft. long, weighs between 375 and 425 lb. A built-in tub of formed metal of comparable length, made from a 14-gage sheet, 42x84 in., weighs between 110 and 125 lb. A cast iron kitchen sink, 60 in. in length, weighs from 225 to 250 lb., while the same size of formed metal sink weighs 60 to 75 lb. Yet the formed metal ware is more than strong enough to stand ordinary use.

Fabricators of the new formed metal sanitary ware have found that their handling and freight costs are appreciably reduced. On the average, it can be said, formed metal is one-third of the weight of cast iron. Installation work requires the services of fewer men. Statistics compiled in a Northern state showed an average of about \$3.50 per unit saved on shipping and installation costs alone.

New and modern designs in fabrication not only are possible but they have become a distinct reality under the guidance of skilled craftsmen. It is possible to complete a kitchen or bathroom with every metal unit harmonized, whether it be in style, or colors, or both — so diversified are the models offered.

*All Sanitary Ware in This Modern Installation Is Colored Porcelain Enamel on Pressed Sheet Steel. Note the wall panels of embossed metal, stainless steel jointures and chromium plated plumbing fixtures*



## Properties of the

# 9% CHROMIUM STEEL

(an intermediate alloy)

**C**ONTINUED DEVELOPMENT OF OIL REFINERY PROCESSES (such as cracking, reforming, stabilizing, hydrogenation, and polymerization of refinery and natural gases to produce high anti-knock gasoline) has led to the wide use of alloy steel tubes in cracking furnaces and other parts of refinery equipment. Perhaps the widest application has been of steel tubes containing 5% chromium and 0.50% molybdenum for the milder conditions of temperature, pressure and corrosion. The more expensive 18% chromium, 8% nickel alloy is also used for the most severe conditions. Large tonnages of these high alloy steels have been used over the past five years or more.

Recognizing a need for an intermediate alloy steel between 18-8 and 5% chromium steel, insofar as oxidation resistance, corrosion resistance and creep strength are concerned, the Babcock & Wilcox Tube Co. has made an extended survey for such an alloy which might still be appropriately priced. Briefly, the requirements of a satisfactory material for high temperature service may be outlined as follows:

1. It must have good corrosion and oxidation resistance up to the maximum service temperature for which it is designed.

2. Its creep strength must be satisfactory.

3. The alloy must be structurally stable under long-time heating within the service range and be free from embrittlement on cooling.

4. It must be suitable for tubing manufacture and have satisfactory forming and working properties.

With the foregoing requirements in mind and with the objective of sup-

plying a material suitable for service temperatures up to about 1250° F., a chromium content of 9% was selected. This is nearly double that contained in the well known 4 to 6% chromium steel and is exactly one-half of the chromium content of 18-8. Such an amount was deemed adequate to provide the desired resistance to corrosion and oxidation. Strength at high temperature was then improved by adding elements such as molybdenum, vanadium and tungsten, which are strong carbide-formers.

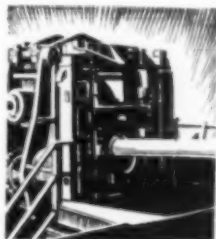
### Experimental Melts

A series of induction furnace melts was made to determine the individual and collective effect of these elements. Carbon, manganese, silicon and chromium were held as nearly constant as possible to the following limits: Carbon 0.15% max., manganese 0.50% max., silicon 0.50% max., chromium 8.00% to 10.00%. Analyses of the experimental melts are given in the first table on the next page. They were made in magnesite crucibles, deoxidized with manganese and silicon and poured into 60-lb. ingots with hot tops. Ingots were reheated and forged to 1-in. rounds for test purposes.

Bars from all heats were annealed together in one bundle by furnace cooling from 1600° F. to 1000° F. at a rate of 25° per hr. This provided a common basis for evaluating the effects of variation in analysis. Physical properties of each steel, as annealed and tested at room temperature, are given in the second table. Yield point was determined by dividers set 0.020 in.

by **H. D. Newell**

Chief Metallurgist  
Babcock & Wilcox Tube Co.  
Beaver Falls, Pa.



### Chemical Analyses of Trial Heats

Heat	C	Mn	Si	Cr	Mo	V	W
<i>Exploratory Series</i>							
604	0.14	0.54	0.10	8.35	0.57	—	—
605	0.17	0.47	0.05	8.40	—	0.21	—
606	0.12	0.45	0.12	8.64	—	—	1.00
607	0.13	0.38	0.07	8.72	0.53	0.26	—
608	0.13	0.42	0.13	8.95	0.59	0.23	1.04
609	0.08	0.42	0.17	9.10	—	0.25	0.97
610	0.07	0.42	0.20	8.69	0.55	—	0.95
611	0.11	0.46	0.12	8.33	—	—	—
<i>Molybdenum Series</i>							
800	0.12	0.49	0.17	8.94	—	—	—
801	0.11	0.45	0.09	9.32	0.30	—	—
802	0.09	0.38	0.17	9.28	0.50	—	—
803	0.10	0.38	0.12	9.54	0.98	—	—
804	0.12	0.38	0.09	9.42	1.41	—	—
805	0.10	0.36	0.16	9.58	1.85	—	—
806	0.10	0.36	0.19	9.58	2.95	—	—

over gage length. The Charpy impact specimen was 0.394 in. square with key-hole notch; impact values are average of two tests except those marked (4).

The benefits derived by adding the carbide-forming elements were evaluated by means of the "short time, high temperature tensile test." These tests were made in the usual manner; specimens were 0.505 in. diameter and 2 in. gage length, with threaded ends. The specimens were inserted into grips made of heat resisting alloy and heated in a tube furnace placed between the heads of a hydraulic testing machine of the Amsler type. Iron-constantan and platinum thermocouples were attached to the specimen during heating and pulling, the furnace temperature being maintained constant for each test by means of a potentiometer type controller with an additional platinum couple adjacent to the wall of the furnace.

Testing conditions were standardized and made in accordance with A.S.T.M. tentative standard E21-34. Pulling speed in all cases was 0.10 in. per min. Although yield points were taken from the stress-strain diagrams and elongation and reduction of area recorded for all tests, the index taken for the effect of the element was the ultimate strength.

Yield points show the same general relation-

ships as the ultimate strengths. They are not recorded here, because such values are usually determined by some arbitrary method; various laboratories fail to agree on the results. Further, the figures are not useful for design purposes.

### Short Time Tests

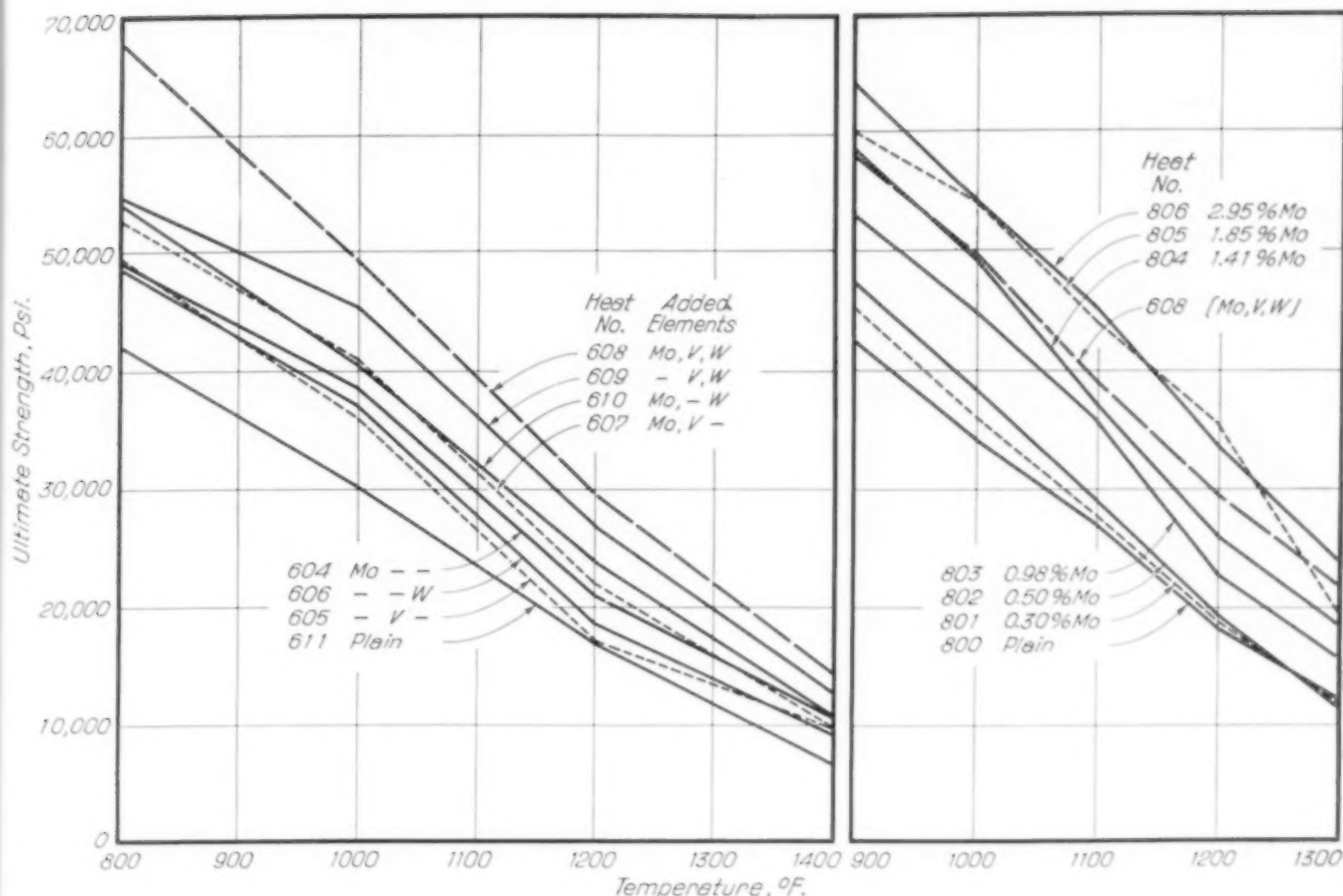
While the value of figures for the short time, high temperature test is a matter of controversy, it should be remembered that we were at this point merely trying to find the alloy which would be most likely to have superior creep strength when tested for 1000 hr. It is apparent that all the analyses could not be investigated in reasonable time by this time-consuming method. It is also our experience that in the older, more firmly established materials, the short time strength when determined under standardized conditions furnishes a rough index of the creep at high temperature, although there is no constant ratio between the two values. For example, the figures for short time ultimate strength of 0.10 to 0.20% carbon steel, 5% Cr with 0.50% Mo, and 18-8 at 900, 1000, 1100, and 1200° F. respectively, all place the carbon steel weakest and 18-8 strongest—a relation which also holds on careful creep testing at the same temperatures.

### Properties of Annealed 8-10%Cr Steels at 70°F.

Heat No.	Added Elements	Ultimate Strength Psi.	Yield Point Psi.	Elongation in 2 In.	Reduction of Area	Brinell	Charpy Impact Ft-Lb.
<i>Exploratory Series</i>							
604	Mo	68,400	33,600	36.5%	71.8%	122	44.5
605	V	68,850	28,750	37.5	74.5	124	53.7
606	W	69,050	28,300	37.5	75.1	126	41.0
607	Mo, V	70,250	40,400	36.0	71.3	140	47.5
608	Mo, V, W	80,350	53,800	29.5	68.6	174	39.0
609	V, W	77,900	47,900	35.0	70.7	174	48.0
610	Mo, W	70,370	34,500	36.5	75.3	134	57.7
611	Plain	60,850	29,400	39.0	77.5	111	58.0
<i>Molybdenum Series</i>							
800	Plain	69,300	26,025	34.0	68.7	135	58.5
801	0.30% Mo	71,000	27,800	37.5	79.1	131	—
802	0.50% Mo	71,950	27,480	37.5	76.4	137	—
803	0.98% Mo	76,800	35,230	38.5	78.8	143	77.5(4)
804	1.41% Mo	81,500	41,800	34.5	76.9	143	63.0
805	1.85% Mo	85,300	51,650	37.0	78.0	149	55.5(4)
806	2.95% Mo	85,900	42,700	31.5	65.6	152	—

The curves at the left on page 53 show the short time strength of the alloys in the 600 series; it may be observed that molybdenum is the most effective single element and vanadium the least effective of the addition elements tried. The





Short Time Tensile Tests on Series 600 (Left) Indicate That Either Molybdenum, Vanadium or Tungsten, Alone or in Combination, Improve Strength of 9% Chromium Steel at High Temperatures, But That of These Molybdenum Is Most Potent (Series 800 at Right)

ratios employed in these additions were 0.5 V = 1 Mo = 2 W. The short time strength of the plain 8 to 10% chromium steel was improved in every case by the addition elements, and a decided rise in strength was secured in the steel containing all three elements (heat No. 608).

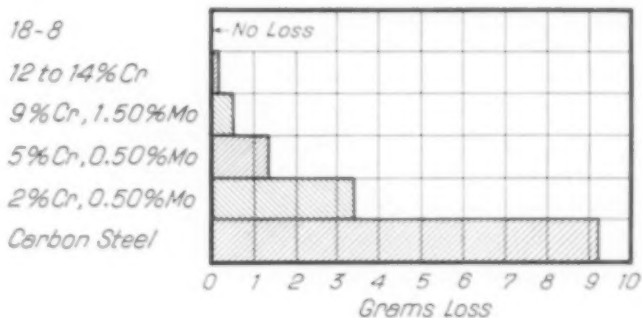
### Advantages of Molybdenum

Molybdenum was favored for the reasons that it is the most effective in raising strength for a given cost. It is also a metal of which an ample supply is certain from American ores. Molybdenum has proved itself highly effective in removing "temper brittleness" in the plain 4 to 6% chromium steels, and it was anticipated that its presence would prevent any such trouble in the new 9% chromium steel.

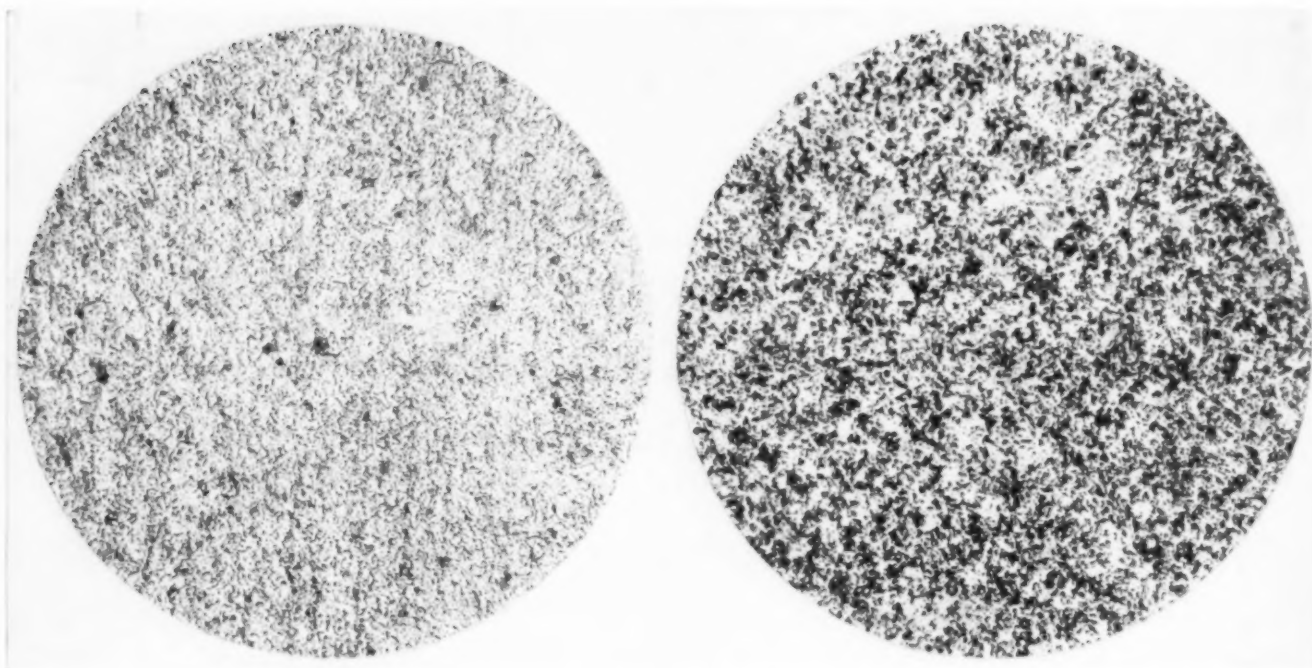
Therefore a second series of steels containing 9% chromium was made and tested, containing molybdenum in graduated steps (series 800). The increase in strength obtained with increased molybdenum content is shown graphically in the right hand set of curves, which indicates that in-

crease in strength occurs up to 1.85% molybdenum, above which the strength is but little improved. The short time properties of steel 608 with three elements (Mo, V and W) were duplicated or even surpassed by a suitable molybdenum addition (steel 805).

**Oxidation Resistance.** The molybdenum series of alloys were tested for oxidation resistance at a selected temperature of 1200° F. It was observed that molybdenum slightly accelerated oxidation when compared to the plain 8 to 10%



Losses in 250 Hr. in Oxidizing Atmosphere at 1200° F. Are Inversely Proportional to Chromium Content



*Microstructure of 9% Chromium, 1.5% Molybdenum Steel.  $\times 100$ . Etched with copper sulphate and hydrochloric acid. At left is structure after air cooling from 1750° F.; Brinell hardness is 329. At right is annealed structure (ferrite and spheroidized carbides) after furnace cooling; Brinell 158*

chromium steel. This is believed due to the volatility of molybdenum at a red heat. It does not, however, cause appreciable loss of the alloy on heating as evidenced by the fact that a melt containing 1.43% molybdenum showed 1.41% molybdenum in the surface layers of the specimen after removing scale formed at 250 hr. at 1200° F.

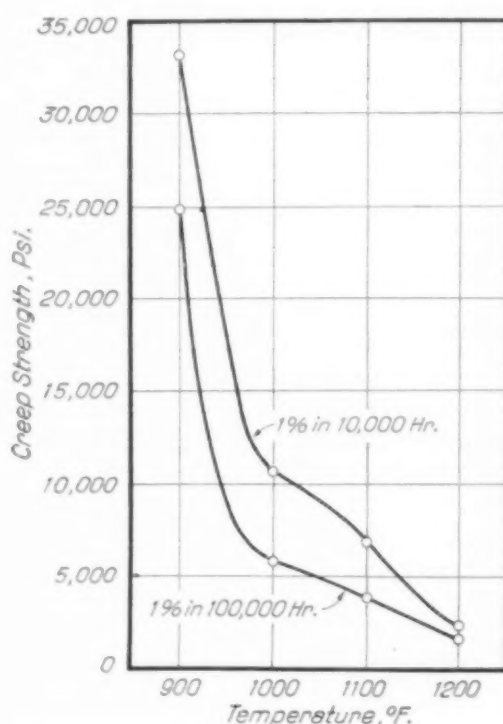
The comparative oxidation resistance of the chromium steels at 1200° F., is sketched at the bottom of page 53. Machined specimens  $\frac{3}{4}$  in. diameter  $\times$  2 in. long were mounted on a circular ring holder and heated in an oxidizing atmosphere for 250 hr. Specimens were cooled ten times to room temperature without scale removal during the run, whereupon the scale formed was removed and weight losses determined.

**Microstructure** — Structurally, the plain 8 to 10% chromium-iron alloys with 0.10 to 0.15% carbon are martensitic, and thus air harden to about the same extent as the plain 5% chromium steels. The presence

of considerable molybdenum suppresses these hardening reactions and stabilizes a portion of the structure so that it retains the body-centered cubic space lattice from the time it solidifies down to room temperature, without intermediate transformation. In other words, if the carbon content is sufficiently low with chromium and molybdenum toward the high side of the range, the air

hardening tendencies are not very pronounced. In extreme cases the structure will be mostly soft alpha-delta ferrite with minor martensitic portions; the latter portions have gone through the transformations into gamma iron or austenite and part way back again to a hard constituent containing free carbide.

It is generally preferable to balance the chemical composition so as to have a transformable alloy, in order to permit heat



*Creep Strength of 9% Chromium, 1.5% Molybdenum Steel, Determined by F. H. Norton, Massachusetts Institute of Technology*

treatment and preserve impact properties. Two photomicrographs show the structure of the approved alloy in the air hardened state and after annealing. The annealed structure consists of ferrite and spheroidized carbides.

### Creep Strength

Determination of the creep properties of certain of the annealed molybdenum steels was undertaken by Prof. F. H. Norton using procedures described in METAL PROGRESS for October, 1933. Data developed for the 9% chromium, 1.50% molybdenum alloy are plotted in curve form on page 54. Its creep values in comparison with 5% chromium-molybdenum steel and 18-8, as found by the same investigator, are shown in the table below.

#### Creep Properties of High Chromium Steels

Material	900°F.	1000°F.	1100°F.	1200°F.
<i>0.10% in 1000 Hr. (1% in 10,000 Hr.)</i>				
5%Cr, 0.50%Mo	17,900	9,200	4,800	1,800
9%Cr, 1.50%Mo	33,250	11,650	6,950	2,300
18%Cr, 8%Ni	24,000	18,300	11,550	5,500
<i>0.01% in 1000 Hr. (1% in 100,000 Hr.)</i>				
5%Cr, 0.50%Mo	15,000	7,200	2,400	900
9%Cr, 1.50%Mo	24,750	5,800	3,775	1,600
18%Cr, 8%Ni	18,000	11,500	7,100	4,250

**Chemical Analysis.** After completing these tests and considering the economic factors, the chemical composition range selected for the new steel was as follows:

Carbon	0.15% max.
Manganese	0.50% max.
Silicon	0.50% max.
Chromium	8.00 to 10.00%
Molybdenum	1.25 to 1.75%

Nominal composition within this range is 9.25% chromium, 1.50% molybdenum, 0.12% carbon. A trade name of "Croloy 9" has also been chosen for the alloy.

**Workability and Utility.** The alloy has stainless properties approaching those of 12% chromium-iron alloys and for this reason may be termed "semi-stainless" as contrasted to the complete stain resisting qualities of 18-8 and the non-stainless qualities of 5% chromium steels. Perhaps this designation of semi-stainless is inept from a technical standpoint but it gives a concise practical description of the alloy.

Corrosion tests to determine suitability for high temperature, high pressure application can-

not be appropriately made in the laboratory; consequently the alloy is now being tested in the industry for which it was designed. Tubes are in service in many oil refineries throughout the country and the answer as to whether or not the alloy fills a need will be determined by the user.

At the present writing, some ten commercial electric furnace heats have already been processed into seamless tubes; all indications are that the alloy can be satisfactorily handled when rolling bars and when piercing and rolling tubes. Annealed tubing of the alloy has good ductility and may be readily expanded, formed or bent. Welding practices must follow those acceptable for 5% or higher chromium steels.

### Impact Strength

"Susceptibility ratio" tests of impact specimens show the alloy to be free from any tendency toward embrittlement when cold with excellent ductility when hot. Representative impact values may be given for a bar previously water quenched from 1650° F. and drawn 4 hr. at 1200° F. When water quenched from the draw the impact was 38, 40 and 41 ft-lb. When furnace cooled at 25° F. per hr. to below 700° F. the impact was 36, 43 and 39.5 ft-lb. There is thus little change in toughness due to the rate of cooling.

The material has thermal expansion characteristics slightly lower than carbon steel. Data are as follows:

Temperature Range	Mean Coefficient
70° F. to 300° F.	$6.28 \times 10^{-6}$
70° F. to 600° F.	$6.67 \times 10^{-6}$
70° F. to 900° F.	$7.00 \times 10^{-6}$
70° F. to 1000° F.	$7.30 \times 10^{-6}$

Tubes of the alloy will consistently meet the following minimum physical requirements: Tensile strength, 75,000 psi.; yield point, 30,000 psi.; elongation in 2 in., 30%; and Brinell hardness, 180 max.

From the foregoing description of this alloy it is apparent that its properties suggest suitability for somewhat severe service up to about 1250° F. metal temperature in such applications as furnace tubes and heat exchanger tubes for oil refining and for superheater tubes in steam boilers. Other uses will undoubtedly be found where the properties of the alloy are suitable. In this connection, it may be remarked that appropriate quenching and tempering heat treatments can produce a wide variety of physical properties which may be of use for mechanical parts such as bolts and studs.



## Physical properties of

# BABBITT

## tin base bearing alloys

**T**IN-BASE BEARING METALS, KNOWN COMMERCIALY as "babbitt metals" or "babbitts," are essentially alloys of tin, antimony, and copper, to which as much as 30% of lead may be added—largely for the purpose of reducing their cost. Of the elements which materially improve these alloys cadmium is perhaps the most important; nickel is also stated to be of value. Of elements to be avoided entirely, zinc and aluminum are the most important. Arsenic, bismuth, and iron should be limited in amount. Specification B 23-26 of the American Society for Testing Materials (endorsed by the American Foundrymen's Association) and the specifications of the Society of Automotive Engineers for white bearing metal alloys may be referred to in this connection.

A.S.T.M. grade No. 1 and S.A.E. specification No. 10 are about the same, being nominally 90% Sn, 4½% Cu, 4½% Sb. This babbitt is very fluid and may be used for bronze-backed bearings, particularly for thin linings such as are used in aircraft engines.

S.A.E. No. 11 is nominally 80% Sn, 5¾% Cu, 6¾% Sb. This is a rather hard babbitt which may be used for lining connecting rod and shaft bearings which are subjected to heavy pressures; its wiping tendency is very slight.

Specification No. 12 (nominally 60% Sn, 3% Cu, 10½% Sb and 26% Pb max.) is a relatively cheap babbitt and is intended for bearings subjected to moderate pressures. All of these analyses are suitable for die castings.

The presence of zinc and arsenic in bearing metals is looked upon with disfavor. According to several authorities,

arsenic increases the resistance of these alloys to deformation at all temperatures; while zinc has a similar effect at 100° F., it causes little or no change in their properties at room temperature. Zinc has been found to have a marked effect upon the microstructure of certain of these alloys, the cubes of SnSb normally present tending to coalesce and form star-shaped groups. Though normally of a reddish hue, the alloys become white when as little as 0.032% zinc is added.

Small quantities of aluminum (for instance, 1.0%) modify the microstructure of these alloys, causing the cubes to disappear. Alloys containing aluminum have a fine, globular structure when rapidly solidified, but the aluminum (in combination with a little copper and some antimony) tends to rise to the tops of castings during slow freezing.

Bismuth is objectionable because it forms with tin a eutectic which melts at 279° F., thus lowering the strength at temperatures in excess of this.

In high-tin alloys (such as A.S.T.M. No. 1) lead is limited to 0.35%. This is because of its deleterious effect upon strength at temperatures above 300° F., for the lead eutectic melts at 360° F.

Cadmium is without appreciable effect on the microstructures of these alloys if lead be absent. When lead is present, it forms with cadmium and tin a ternary eutectic which melts at 293° F. Bearings containing this combination, therefore, cannot be operated at temperatures in excess of this point without danger of wiping and serious loss of strength.

**By Owen W. Ellis**

Director of Metallurgical Research  
Ontario Research Foundation  
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Extracts from a contribution for the next edition of National Metals Handbook

The various alloys covered by the A.S.T.M. specification have been intensively studied by Freeman and Woodward, and Technologic Paper No. 188 of the National Bureau of Standards should be consulted for their results, entirely too voluminous for inclusion here.

In association with G. B. Karelitz, the present author has studied the tin-antimony-copper system as high as 10% antimony and 8% copper. From the mass of data published by them in *Transactions, American Society of Mechanical Engineers*, 1928, it is apparent that both elements harden and strengthen in a consistent manner within these limits. Thus, holding the copper constant at 0.5%, the 2% antimony alloy has 9.5 Brinell and 7560 psi. compressive strength (load per unit initial area required to compress test pieces 0.250 in. per in. length), whereas the 8% antimony alloy has 18.6 Brinell and 13,960 psi. compressive strength. If, on the other hand, copper is increased, the physicals increase also; with 8% copper and 2% antimony the hardness is 15.3 and the compressive strength 12,080 psi., while with 8% copper and 10% antimony these figures are 30.4 and 18,420 respectively.

A most important point brought out by Freeman and his collaborators was that the total deformation of the sample in compression testing of babbitts is a function of the time of application of the load—a point sometimes overlooked by those reporting and studying results of tests on materials as plastic as are these alloys. What is true of the compression test is true also of other types of static test. However, the known limitations of static tests do not discount their value; a Brinell test, for example, wherein the load is applied for a standard time (say, 30 sec.) is of considerable value for purposes of manufacturing control.

The relationship between the properties of the tin base bearing metals in compression and their Brinell hardness numbers is close enough to permit a fair estimate to be made of their yield points and other properties in compression, given their hardness numbers. Further, a relationship seems to exist between the endurance limits, tensile strengths and Brinell hardness numbers of these alloys.

The endurance limit (20 million cycles) of a tin base bearing metal containing about 3.5% copper, 0.25% lead, 0.03% arsenic and a trace of iron, poured at 660° F. into a mold at 300° F., increases from about 3400 psi. with 3% antimony to about 4400 psi. with 6% antimony, and to about 4800 psi. with 9% antimony. Concurrently, the

tensile strength when tested at a straining rate of 1.2 in. per sec. increases from about 7800 psi. to about 11,200 psi. and about 13,500 psi., respectively, while the Brinell hardness number (125-kg. load; 10-mm. ball; 30 sec.) rises from 15 to about 21 and about 26, respectively.

The impact resistance of tin base bearing metals closely resembling A.S.T.M. grades No. 1 and 3 has been measured by Herschman and Basil. They find that the Izod impact of grade No. 1 is 2.5 at room temperature, and rises to 3.2 ft-lb. at 300° F., and then drops off to 2.2 ft-lb. at 400° F. Grade No. 3 (nominally 83% Sn, 8.3% Sb, 8.3% Cu) has only 0.75 ft-lb. Izod impact strength at room temperature, but toughens slightly and gradually to 1.25 ft-lb. at 400° F.

The results of experiments by Karelitz and Ellis on the rolling of tin base babbitts show the extent to which these alloys can resist plastic deformation without rupture. Carefully machined samples, 1½ in. long, 1 in. wide, and ½ in. thick, were given 13 passes through highly polished, 6-in. rolls, the reduction in thickness per pass being 0.025 in. The final thickness of the samples was therefore 0.175 in. No cracks were observed with lower alloy contents than 0.5% copper plus 6% antimony and 4% copper plus 4% antimony, and only a very few cracks occurred when the antimony in the 4% copper babbitt was increased to 8%.

#### **Wear Tests on Various Babbitts**

Herschman and Basil also conducted wear tests on these alloys, using a modified Amsler test in which a steel wheel (Brinell hardness about 240) rolled in circumferential contact with a babbitt tire. A load of 5 lb. was placed on the steel wheel during test, and a stream of kerosene was directed onto the babbitt near its area of contact with the steel. The losses of weight per 1000 revolutions of grades No. 1 and 3 were about the same and were definitely lower than those of the other A.S.T.M. grades, a lead hardened with an alkaline earth, and an 82:18 cadmium:zinc. The most resistant alloy tested, and it wore three times as much as grade No. 1 or 3, was a modified A.S.T.M. grade No. 8. (5% Sn, 15% Sb, 80% Pb) with 1.0% Cu, 0.6% As, 0.2% Cd and 0.2% Ni.

Service tests on crank shaft bearings made of grade No. 1 alloy, "hardened lead," grade No. 10 alloy, and a 90:10 Sn:Cu alloy frequently used in U.S. Army truck motors showed that the tin base alloys were superior in their wear resistance

to both the "hardened lead," and lead-antimony-tin alloy containing about 3% tin.

The results may here be noted of tests made by Jakeman and Barr on behalf of the British Non-Ferrous Metals Research Association, with the primary object of ascertaining the comparative chemical action of lubricants upon tin base and lead base bearing metals. They found that under their conditions of test (using a journal friction testing machine with bearings fully lubricated by continuous circulation of oil) there was no marked chemical reaction between lubricants and alloys except where oils containing free fatty acid were used with alloys containing high percentages of lead. The tests also showed that, generally speaking, bearings made of high lead alloys showed greater frictional losses and wear than those made of high tin alloys.

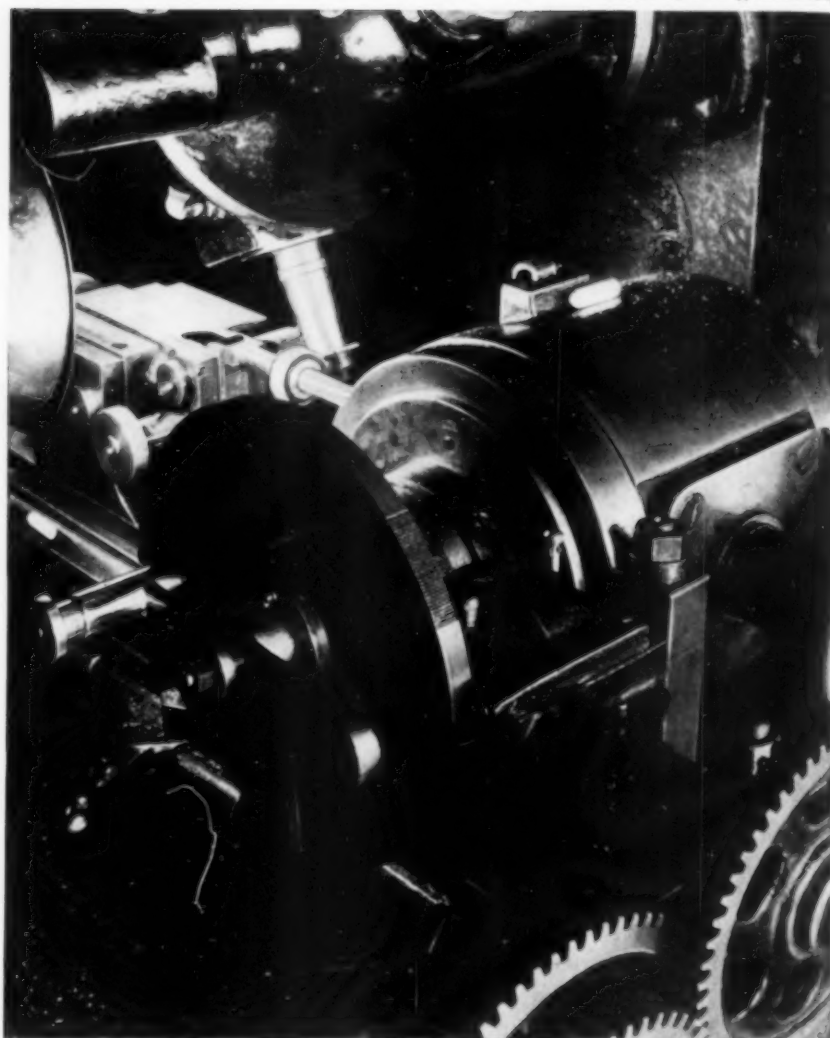
### Effects of Cadmium

Reference has already been made to alloys containing cadmium. Macnaughtan has studied the babbitts containing 3½% copper and 0.04% lead. He finds that 1% cadmium increases the tensile strength of the 4% antimony babbitt by 800 psi., and of the 12% antimony babbitt by 2500 psi., intermediate alloys being strengthened proportionately. Brinell hardness numbers are increased consistently 6 or 7 numbers.

The results of work by Haigh on an alloy containing 3½% copper and 7% antimony indicate that 1% cadmium increases its endurance limit at room temperature from about 4600 psi. to about 5500 psi. on the basis of 20 million reversals of stress.

Göler and Sachs state that the hot strength of these alloys is "markedly increased at temperatures up to 350° F. The running properties are favorably influenced by the addition of cadmium. From the aspect of foundry technique these alloys do not exhibit any peculiarities as compared with the usual high tin white metals."

The behavior at high temperatures is con-



*Bearings Everywhere, of Highest Durability and Precision*

siderably affected by small changes in composition. Bismuth or lead is objectionable on account of the fusibility of the eutectics which these metals form with tin. Opinions differ, though unimportantly, as to the effect of lead at high temperatures; without doubt it somewhat increases the strength and hardness of tin base bearing metals at room temperature. Grant has remarked: "In the author's experience no failures that could be attributed to lead have been observed, although as much as 6 or 7% has not infrequently been found in bearings subjected to severe usage." This is a point of some importance. The fact that the high lead alloys in A.S.T.M. and S.A.E. specifications find extensive use fully confirms Grant's observation. However, to use such alloys in the form of thin linings for automotive and aircraft bearings is quite impracticable, not only on account of difficulties of assembly, but also because of their known failure to meet service requirements.



Room temperature strength, acquired by a little lead in high tin babbitts, is almost entirely lost at temperatures between 200 and 250° F. Boegehold and Johnson report that 2% lead added to a babbitt containing 7.5% each of antimony and copper will cut the compressive flow point from 500 psi. to 200 psi., the tensile strength from 1600 psi. to 500 psi., and the elongation in 2 in. from 116% to 1.0% — all these tests being performed at 400° F. These results indicate that little is to be gained by introducing lead into high tin alloys for the mere purpose of increasing their resistance to deformation, save where the temperatures of the bearings will not exceed about 200° F.

Work must still be done on the effect of copper on the strength of tin base bearing metals at high temperatures. A consensus supports the

view that increase in copper beyond about 3½% lowers their resistance to certain types of severe service, even though copper does increase both hardness and strength in these alloys. The remarkable behavior, for example, of A.S.T.M. grade No. 1 in the form of linings only 0.02 or 0.03 in. thick for connecting rod and crank shaft bearings of automobile and aircraft engines has yet to be logically explained. In this connection, it may be noted that the compressive stress required to cause plastic flow is raised as the ratio of the initial area under compression to the thickness of the metal is increased. For instance, in the testing of lead, all other conditions being equal, the apparent proportional limit in compression is 1800, 3000 or 3200 psi., depending on whether the test piece is 0.25, 0.50 or 1.0 in. square respectively in cross section.

## Changes in Iron and Steel During Creep

by C. H. M. Jenkins and G. A. Mellor

*Condensed from Journal, Iron & Steel Institute*

**C**HANGES WHICH OCCUR IN IRON AND SOFT STEEL under stress at high temperature are of two types, (a) those proceeding as a result of the heat, and (b) those resulting from plastic flow. The tests described in this paper were made in a vacuum over a wide range of temperature (650 to 1650° F.); the rate of loading was such as to cause failure either in a few minutes, as in the "short time tensile test," or in a moderate time — mostly less than ten days.

Polished specimens were tested so that the surface conditions as well as the interior could be examined microscopically after the test. The surface appearance of a broken specimen is not always similar to that observed on longitudinal sections. For example, the surface may show the presence of slip planes, a widening of the grain boundaries, and a general crumpling and corrugation of the surface, but these may extend only to a depth of a crystal or two and the interior structure does not necessarily show appreciable change — that is, as examined after sectioning, polishing and etching. Such surface differences are produced by localized stress set up in partly unsupported crystal grains.

Materials tested were as follows: A 0.24% carbon basic open-hearth steel; a 0.17% carbon acid open-hearth steel; two varieties of Swedish or Lancashire wrought iron; two lots of Armco ingot iron; one rod of carbonyl iron, sintered

and rolled. Some conclusions drawn from the test data and numerous micrographs follow:

Three principal forms of movement occur during plastic flow: (1) Slip movement on the cleavage planes of the crystals and a general adjustment of crystal dimensions to accommodate the elongated crystals within the aggregate. (2) General movement in the grain boundary material accompanied by auxiliary movement within the grains. (3) Movement beginning by slip or grain boundary change, but proceeding after the initial period by contemporaneous recrystallization of the strained material.

The tests show that the extent of each of the above stages depends on the material, the temperature and time of test, and the degree of deformation. Thus, in short time tensile tests the maximum value of the ultimate load on iron and soft steel occurs at a temperature of approximately 500° F. The softening range, as determined by the recrystallization of "cold worked" material, is in the vicinity of 850 to 1100° F. but in creep tests this range of temperature is lowered to nearly 200° F., since "softening" (in the above sense) by heat treatment occurs more rapidly when accompanied by simultaneous deformation. If plastically deformed material is reheated in a certain low temperature range sensible aging occurs and hardening is developed.

*(Continued on page 80)*



**R e a d y !**

Photograph by Wm. Rittese

*Metal Progress; Page 60*

**Aircraft requires**

# **WELDING**

**in many parts**

**O**XY-ACETYLENE WELDING IN AIRCRAFT FIRST came into general use during the War on built-up fittings of low carbon and alloy steels. The advantages of the process were immediately apparent—the investment in equipment was small and its adaptability for complicated fittings was particularly convenient. As a result the application of the process rapidly increased in its scope.

With more general use of the process in this industry there developed a necessity for higher strength alloys, which at the same time had to have satisfactory welding characteristics. The steel that seems to have survived the test of time is chromium-molybdenum steel, containing about 1.0% chromium, 0.25% molybdenum, and 0.30% carbon. It is readily welded and with proper technique the welded parts are reliable. It has the advantage of a tensile strength of about 90,000 psi. in normalized condition, 80,000 psi. as welded, and is regularly heat treated to as high as 200,000 psi. on landing gear parts. In wing beams and other parts subject to vibration, the maximum usable strength is from 160,000 to 180,000 psi. This takes advantage of its higher elongation at the lower strengths; above these figures the fatigue values do not increase proportionately.

Today the great majority of designs for landing gear are built of "chrome-moly" tubing of similar chemical analysis, oxy-acetylene welded at joints and then heat treated. For a number of years such tubing was standard for the

construction of fuselage skeletons. Similar wing spars have also been used with considerable success. The last two are only recently giving way to the monocoque, a construction where the skin or covering also carries stresses. In such designs the welding blowpipe is not so convenient. Welded chromium-molybdenum steel, however, will have its place in aircraft construction for many years to come.

Welding of aluminum and some aluminum alloys has also been accomplished successfully with the blowpipe. It has, however, been fairly closely limited to gasoline, oil, and water tanks.

Electric arc welding has been tried on alloy steel parts used for aircraft with some degree of success. It has not come into general use because of the increased time necessary to train personnel, difficulty of control when welding very thin sections, and (probably as much as anything else) to the presence of an already satisfactory acetylene process.

Electric resistance welding of the chromium-molybdenum steel in various forms has been tried but without success. The difficulty is that the almost instantaneous cooling following limited fusion at the very joint has the nature of a drastic quench which hardens and embrittles the spots so much that a subsequent heat treatment is necessary to restore sufficient ductility. It was then found on complicated structures that a considerable proportion of the spot welds made in this manner were lost during the heat treatment. Our conclusion, therefore, was that spot

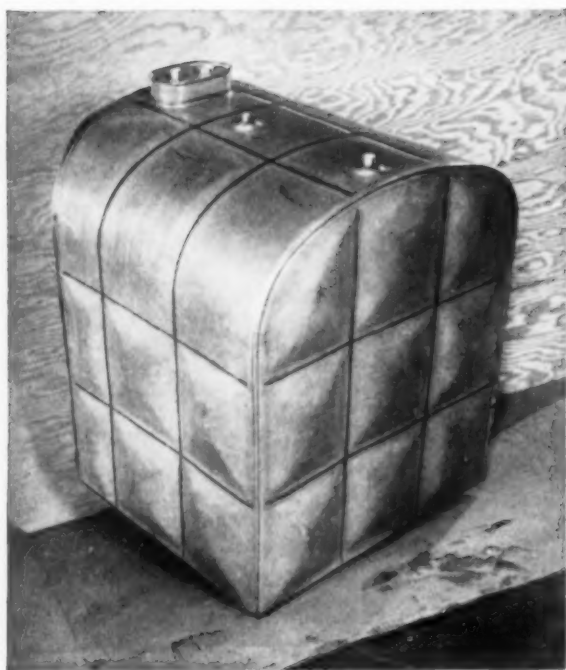
**by Carl de Ganahl**

President  
Fleetwings, Inc.  
Bristol, Pa.



An Address given in December before the New York Section of American Welding Society





*Bulkheaded Tanks of 18-8, Welded With Oxy-Acetylene Process, Weigh 0.50 to 0.70 Lb. per Gallon Capacity. Flat surfaces are crowned to avoid high localized stresses which occur when a thin, flat sheet flexes or "breathes" under variable loadings*

welds on chromium-molybdenum steel were too brittle to be of use without subsequent heat treatment, and that too serious a loss, due to breakage of spot welds, occurred during heat treatment. We therefore abandoned the process.

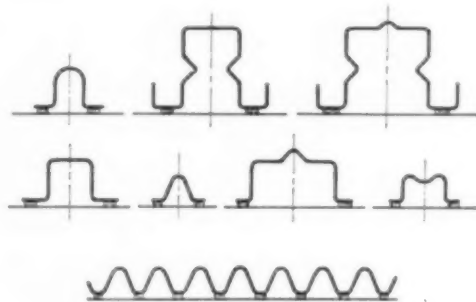
Chromium-molybdenum steel, unfortunately, is not corrosion proof. Corrosion has always been a nightmare to aircraft operators because structures are of necessity so light that they have only the minimum margins of strength. Comparatively thin metal is therefore the rule, and any corrosion would impair the strength below the limits of safety much more rapidly than on static structures where the metal sections are so much thicker. Corrosion protection is therefore a serious consideration on all aircraft parts made of any metal or alloy.

The method now in use for protecting low alloy steel parts is generally as follows: Sandblast, cadmium plate, and then paint. The inside of closed tubing offers a more difficult problem; hot, boiled linseed oil or the equivalent is usually pumped into the tubes through  $\frac{1}{8}$ -in.

holes at each end. After draining off the surplus oil, the holes are closed by small drive screws. In this manner fair protection both inside and outside has been obtained for ordinary use, but it is not adequate against salt air or salt water exposure.

Stainless steel of the 18% chromium, 8% nickel type offered an excellent solution to the corrosion problem, but when it first became available this alloy did not prove so attractive to aircraft manufacturers because of its low yield point, say 35,000 psi. when properly annealed, with an ultimate tensile strength of 80,000 to 90,000 psi. It was, however, tried in places where high strength was not required and corrosion resistance was of importance, such as exhaust manifolds. These were torch welded. The results at first were not satisfactory because any type of fusion welding raises the temperature through the range where carbide deposition occurs in the stainless. Intergranular corrosion and consequent failure resulted.

When hard rolled, high tensile 18-8 became available, its high physical characteristics immediately attracted our attention. Material in the form of cold rolled strip can now be obtained with tensile strength of 185,000 psi., yield point (or stress

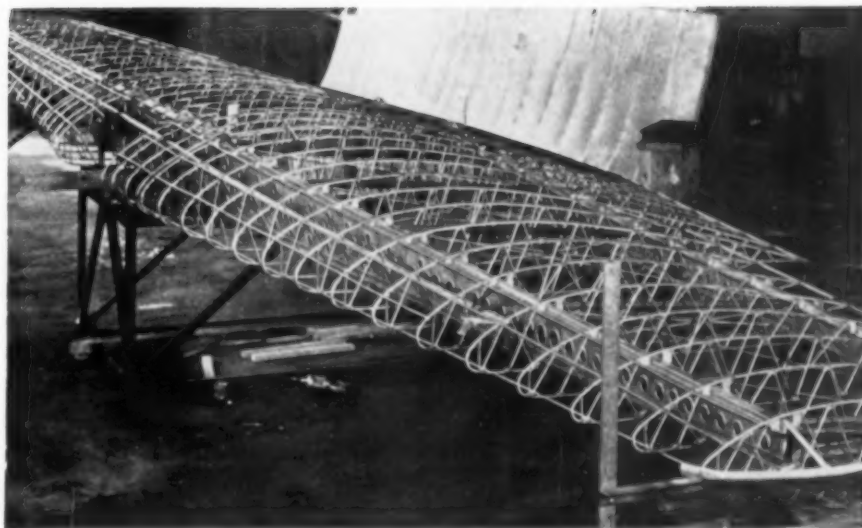


*Tests Show That Stiffened Skin (Monocoque Construction) Is More Efficient When Most of the Stress Is Carried by Heavier Stringers and the Lighter Skin Holds These Stiffeners in Place. Closed sections, with spot welds as indicated, can be used with no fear of corrosion troubles when made of stainless*

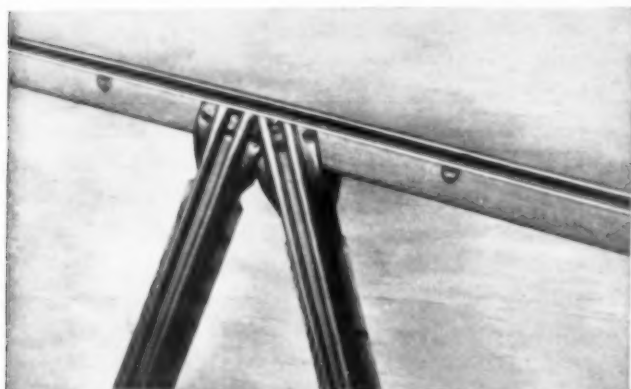
for 0.5% elongation) above 150,000 psi., and elongation of 15% in 2 in. At last, here was a material with high physical characteristics, with excellent resistance to corrosion! But how would it weld?

Unlike chromium-molybdenum steel, sudden chilling from a high temperature does not harden 18-8, it being an austenitic alloy. Consequently spot welding proved an excellent method of fabrication. Ductile spots can be reliably obtained, capable of carrying from 80 lb. to 15,000 lb. per spot, depending on the thickness of material joined. We have continued the development of this art and in the course of time have built welding machines of an entirely automatic character, some of them capable of delivering 960 "shots" per minute. Fleetwings, Inc., is at present fabricating many aircraft parts of high tensile stainless, shot welded.

In the meantime, however, the steel companies have gone to work on remedying the difficulties encountered in fusion welding. As is now well known to metallurgists, that type of intergranular corrosion and failure known as "weld decay" was due to the deposition of chromium carbides within certain temperature ranges and along the crystal boundaries, leaving that region low in available chromium, the main protec-



*Wing Skeleton Made of Cold Rolled 18-8 Strip*



*Advantages of Spot Welds Shown in Junction of Rib Web Members. Welds add no weight; they can be placed close together and at the very edge of the member*

tion against corrosion. By the addition of titanium or columbium to the steel, the carbon is taken up as titanium carbide or columbium carbide, thus preventing interference with the chromium. Stainless steels of the 18-8 type are now available containing one or the other of these elements which can be subjected for a long time to any range of temperature up to 1600 or 1700° F. without any loss in corrosion resistance.

Titanium tends to slag off during welding with the oxy-acetylene blowpipe and its absence is noticeable in the weld metal. Columbium, strangely enough, is much more permanent. Satisfactory results are obtained if either titanium or columbium bearing stainless steels are welded with columbium bearing rods. Exhaust manifolds of such materials are now almost standard with the Navy and the Army Air Corps.

As mentioned before, we are fabricating many aircraft parts of high tensile 18-8 stainless by shotwelding methods. These are corrosion resistant and eminently satisfactory. There are,

however, a great many places where fusion welding would be a tremendous convenience. It is hoped, therefore, that the steel companies will now make high tensile stainless for us that will retain high physicals after fusion welding.

#### **Experience Being Gained**

Looking into the future application of stainless steel in the aircraft industry it is necessary to answer one particular question, "How does its weight-strength ratio compare with the materials at present fashionable?"

Our data indicate that we can build parts in stainless as light as in other materials — frequently lighter. The larger the part and the higher the stresses, the more advantageous the use of steel. The reason for this is that in small parts or parts carrying small stress it is necessary to use minimum gages, and even then the strength is sometimes above that required. Parts made of sheet down to 0.005 in. thick are inclined to be fragile, in the sense that they are easily damaged by careless handling and bumping around. Where high stresses are the rule, thicker gages can be used and full advantage of the high physicals can be taken.

The larger the airplane, therefore, the more suitable the use of stainless becomes. In large aircraft the investment may reach \$1,000,000 and even more. Obsolescence in three to five years, which is the rule at present, is intolerable. With the necessity for increased useful life, the corrosion resistance of high alloy steel becomes of increasing importance, both from the point of view of maintenance and long life.

**Some applications of**

# **X-RAYS**

**to industrial problems**

**T**HE VISIBLE ELECTROMAGNETIC VIBRATIONS OR waves called light, and the shades of red, yellow, green, and blue in a subject are attributable to differences in the wave-length of the light vibrations reflected from the object. X-rays, like light, affect photographic film, and upon development of the film produce a negative exhibiting gradation of shades from black to white similar to that of a photograph. We may therefore quite reasonably expect light waves and X-rays to have a common origin.

Physicists have proved this assumption to be true. X-rays are electromagnetic vibrations or light waves; but whereas visual light waves vary in wave-length from 3900 to 7700 Ångstrom units, the X-radiations are extremely short, varying from 1000 down to 0.06 Ångstrom units in wave-length, only the shortest of them being of any great usefulness in industrial X-ray work.

A third group of vibrations in the electromagnetic series of waves are those known as gamma rays. These are of even shorter wave-length than X-rays and possess still greater ability to penetrate matter. Ultra-violet, visual light, the infra-red, the Hertzian, and the radio or electric waves, as well as the much debated cosmic rays are all part of the electromagnetic wave spectrum. The complete electromagnetic wave spectrum is shown in the diagram, top page 65.

Since X-rays have a common origin with light, we may make some interesting comparisons between them. Both X-rays and light waves are propagated in straight lines, and both may be reflected, refracted, diffracted and polarized. Both are also differentially absorbed by matter.

The great difference between them is that X-rays are able to penetrate objects opaque to visual light and reveal the internal structure of the objects, whereas visual light is reflected from their surfaces.

Just as we may have light of various colors depending upon the wave-length, we have "hard" X-rays or "soft" X-rays, depending upon whether they are in the shorter or longer wave-length section of the X-ray spectrum. A "hard" X-ray, because of its short wave-length, is a ray of high penetration, and is the type desired for work in the industrial field. We may control the quality of "softness" or "hardness" of the rays by controlling the voltage applied to the terminals of the X-ray tube. Consequently when metals of low density or objects of little thickness are under examination, low voltages are used, since highly penetrating rays are not required. But as objects of greater density or greater thickness are examined, higher and higher voltages must be used to produce X-rays capable of penetrating them, because the absorption of the rays by a material decreases for the X-rays of shorter wave-length produced at the higher voltages.

Using a 200,000-volt, air-cooled Coolidge tube, the maximum thickness of steel, for example, that may be X-rayed successfully is approximately 3 in. Metals of higher atomic number like tungsten or lead have a lower limiting thickness, and those of lower atomic number like aluminum

may have somewhat heavier sections successfully X-rayed. Higher-voltage tubes are obtainable but they require water cooling, and are consequently more difficult to maintain satisfactorily.

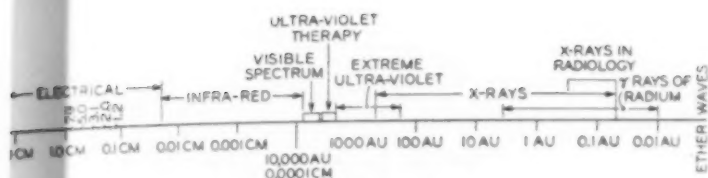
**by J. R. Townsend  
and L. E. Abbott**

Bell Telephone Laboratories  
New York City

From a paper originally presented before Society of Motion Picture Engineers

*Metal Progress; Page 64*





Electromagnetic Wave Spectrum Extends Far Beyond Range of Visible Light in Both Directions

The air-cooled tube will give good service over long periods without maintenance difficulties.

The 200,000-volt Coolidge tube used in our laboratory for X-ray photography in industrial development work is of the two-element type containing a solid metal anode, generally called the target because it is bombarded by electrons from the cathode, which consists of a spiral coil of tungsten wire heated to incandescence by current from an independently controlled circuit. The tube is evacuated to the highest degree possible so that it may be operated with a pure electron discharge. The vacuum attained in the universal type of Coolidge tube is so great that the pressure is reduced to a few hundredths of a bar, the bar representing only one-millionth of standard atmospheric pressure. This gives the Coolidge tube a great advantage over the gas-filled types, as the current through the tube is independent of the voltage between the filament and the target, thus giving the operator complete control over the emission of electrons from the cathode by regulation of the current which heats the filament.

In operating the tube the tungsten wire filament forming the cathode is heated to incandescence, and a high voltage is applied between cathode and target. This voltage hurls the electrons produced by the hot-wire cathode across the several inches of space separating the cathode from the anode, and causes them to strike the metal target with great force. X-rays are produced at the surface of the target and radiate out

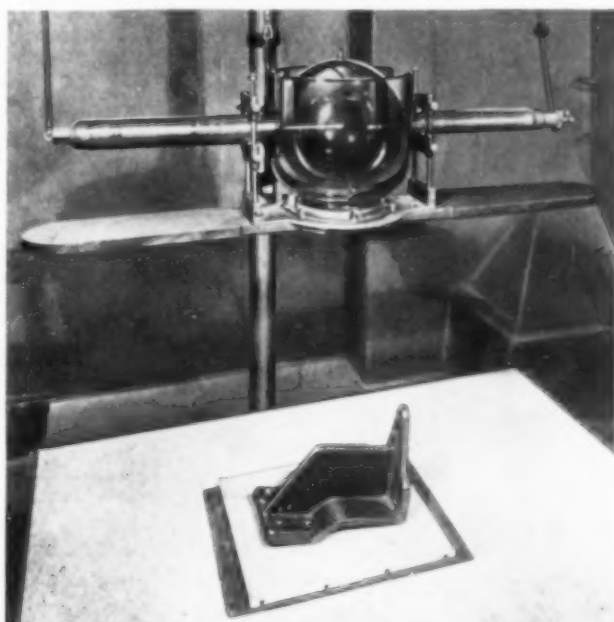
because of the impact of the electrons upon it.

Because of the great similarity between light rays and X-rays, it is possible to draw an analogy between taking a photograph and preparing an X-ray picture or "exograph" of a metallic part for possible defects. In taking a photograph of an object the light reflected from the various portions of the object are focused upon the sensitized surface of a photographic film. Those portions of the object that reflect the most light produce the greatest effect upon the film and, consequently, upon developing the film, the negative shows dark areas at those points. Conversely, those portions of the object reflecting the least light show as light areas upon the developed negative.

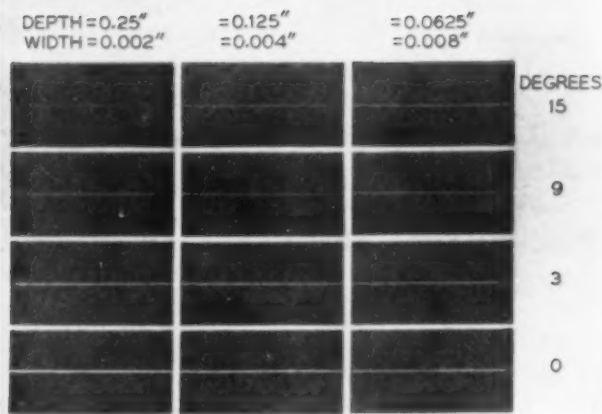
Similarly in X-raying an object, the rays produce light and dark areas upon the developed

negative but instead of X-rays being *reflected* from the object and falling upon the film, as in the case of the photograph, the X-rays *penetrate* the object and fall upon the film, which is placed underneath. The image produced upon the film is therefore a shadow picture, the variations in the shading of which depend upon the absorption of the material at various points, which in turn depends upon the variations in thickness of the object — or, if the object is made of several materials, upon the atomic numbers of the materials involved.

For example, if an exograph is prepared of a sand cast bracket containing inclusions of molding sand, pockets of trapped gas, or shrinkage cracks, we should find that the X-ray negative would have irregular areas of considerably darker shade at the points directly beneath the defects. Since the density of the bracket was lower at the points where the defects occurred, more X-rays were able to penetrate through the metal at those points and strike the film, and therefore the sensitized film was affected to a greater extent at those points; just as



X-Rays Originating in Coolidge Tube Pass Down Through Object Under Study (in This Case a Metal Bracket), Then Through Walls of Cassette and Affect the Photographic Film Inside This Light-Tight Holder



*Artificial Cracks of Same Cross-Sectional Area But of Different Shapes, Cut in 1-In. Steel Plate. Narrow cracks are almost indistinguishable if inclined at a very blunt angle to incident rays. All exographs in this article are negative prints of the films—that is, holes in metal give dark spots on film and light spots on the prints*

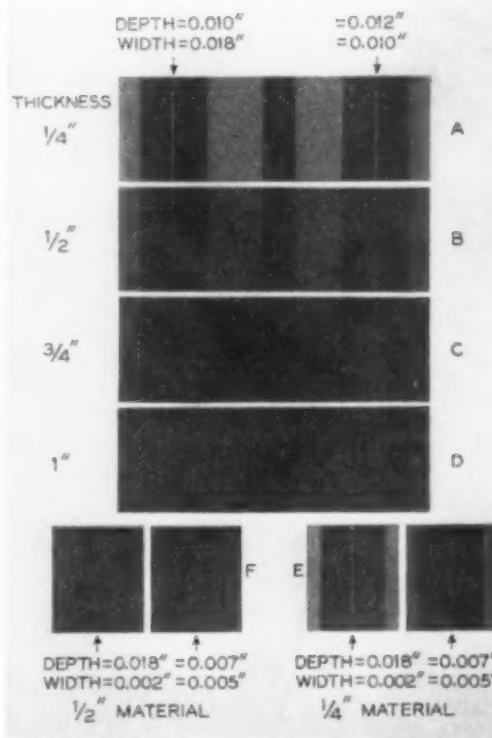
in photographing the film is affected to a greater extent at the points where the greatest amount of light is reflected from the object.

If the bracket being X-rayed had contained inclusions of a material of higher atomic number, globules of lead, for instance, then more X-rays would have been absorbed at that point, because lead has a much higher absorption coefficient than iron. As a result, an area of considerably lighter shade would have appeared upon the developed negative at the point lying directly underneath the lead inclusion. Some illustrations will be presented further on.

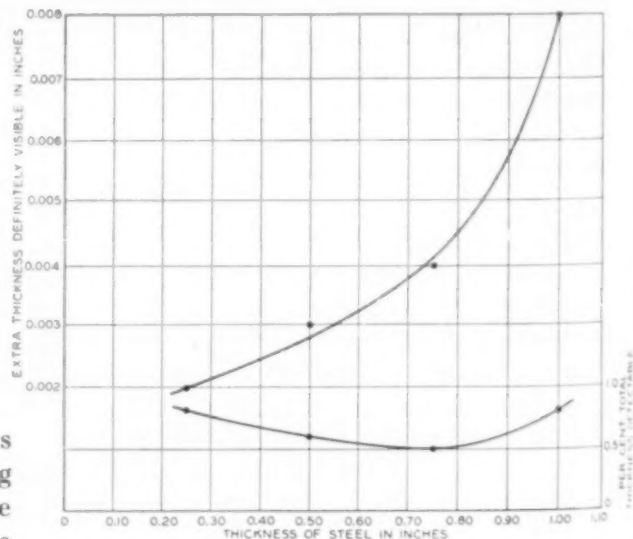
One considerable difference exists between taking a photograph and making an exograph. The quantity of light entering the camera may be controlled by adjusting the shutter, and the lens system sharply focuses the light upon the film. While the quantity and, to a certain extent, the quality of X-rays produced may be controlled fairly well by regulating the milliamperage and voltage of the X-ray tube, there is no known method of focusing these rays, so that fine definition can be obtained in X-ray work only if the source of the rays approximates a point.

Therefore, all the electrons from the cathode must strike the anode, or target, in a very small area so that the X-rays produced will come from as nearly a point-source as possible. To accomplish this a molybdenum shield is usually placed around the cathode to confine and direct the flow of electrons to a focal spot on the target 0.25 in. or less in diameter. The only other control upon the sharpness or definition of an exograph is attained by varying the distance of the tube from the object under examination. The further the tube is placed from the object, the more nearly the X-rays

produced at the small focal spot on the target approximate a point-source. The objection to this method of increasing the sharpness of negatives is that the inverse square law applies to X-rays as well as to light, and consequently any great increase in the distance between the Coolidge tube and the film requires unduly long exposures. Usually a tube-to-film distance of



*Study of Hair-Line Cracks Indicates That Openings About 0.005 by 0.007 In. Are About as Small as Can Be Discovered in 1/2-In. Steel Plate; Such a Negative Cannot Be Satisfactorily Reproduced as a Halftone*



Sensitivity of 200,000-Volt Coolidge Tube in the Detection of Irregularities in Steel. Upper curve gives thickness in inches and lower curve gives thickness detectable in per cent. Greatest sensitivity is on 3/4-in. material

24 in. or, at the most, 36 in. is used to attain satisfactory definition, the 36-in. distance requiring more than twice the exposure time at 24 in. to produce a negative of the same density.

It has been pointed out previously that at present we are limited in the use of practical X-ray equipment to the examination of metallic sections equivalent to a thickness of 3 in. of steel. The question naturally arises as to how small a defect it might be reasonable to expect would be revealed in such a section.

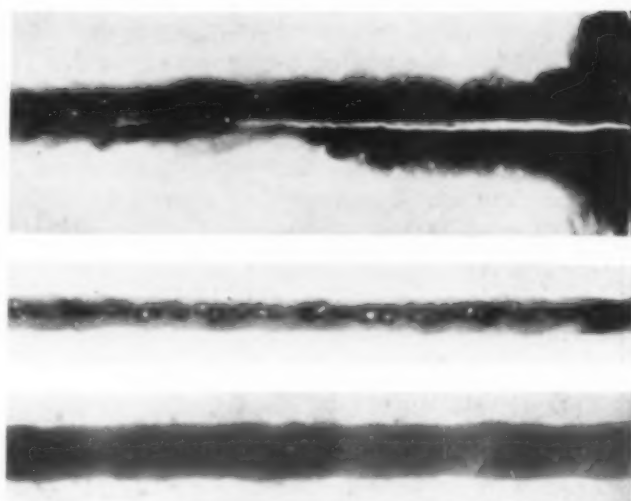
### Sensitivity of the Method

The sensitivity of a radiographic examination depends to a large extent upon the thickness of the section. This might be expected when it is considered that with increasing thickness the problems introduced by absorption and internal scattering of the rays are intensified. The orientation of the defects in the object or the angle at which they occur to the incident X-rays is also of considerable importance.

For example, if a casting contains a crack orientated  $90^\circ$  to the incident X-rays, the width of the crack represents the difference in density that the rays must indicate; whereas, if the crack were parallel to the direction of the rays the entire length of it would furnish a path of reduced absorption for the X-rays. Therefore, cracks lying at angles to the path of the radiation tend to give diffused rather than clear-cut images. This adds emphasis to the importance of making several examinations at different angles when small cracks are suspected to exist in the subject under examination. This phase of X-ray examination has been rather thoroughly studied at Bell Telephone Laboratories in order to establish some quantitative measures.

One series of tests was made by using artificial cracks, of cross-sectional area of 0.0005 sq. in., in a steel plate 1 in. thick. The cracks, however, were varied in depth and width in order to determine the effect of these variables upon the readability of the X-ray negative. In addition, the cracks were X-rayed at orientations that varied from the normal to an angle of  $15^\circ$  between the ray and the plane of the crack.

Results of one such study are shown in the half tones at left. The cracks having the larger ratio of depth to width were more easily distinguished when they were directly in the path of the radiation or lying at very acute angles — less than  $3^\circ$  to the radiation. When the cracks were oriented at angles of  $3^\circ$  to  $15^\circ$ , those with the



*Exographs of Welded Joints, One Showing a Shrinkage or Stress Crack, Another Showing Great Internal Porosity, and the Third a Sound Joint Easily Achieved With Proper Control*

smaller ratio of depth to width were more easily detected. For example, the crack 0.0625 in. deep and 0.008 in. wide shown in the figure can be easily distinguished at a  $15^\circ$  angle, whereas the crack 0.25 in. deep and 0.002 in. wide is practically invisible.

Considerable work was also performed on so-called "hair-line" cracks, or cracks of area smaller than 0.0005 sq. in. The equivalent of this type of artificial crack is often found in castings and forgings, and is the most difficult defect with which the radiologist has to contend. It was found that the limiting cross-sectional area of a crack that could be distinguished in a  $\frac{1}{2}$ -in. steel plate (the thickness most frequently encountered in telephone work) under the best radiographic conditions was 0.000035 sq. in., representing a crack having a depth of 0.007 in. and a width of 0.005 in. These lines can be seen on the film but cannot be reproduced in a half tone. Some of the results on larger cracks in  $\frac{1}{4}$  to 1-in. steel plate are given in the illustration opposite.

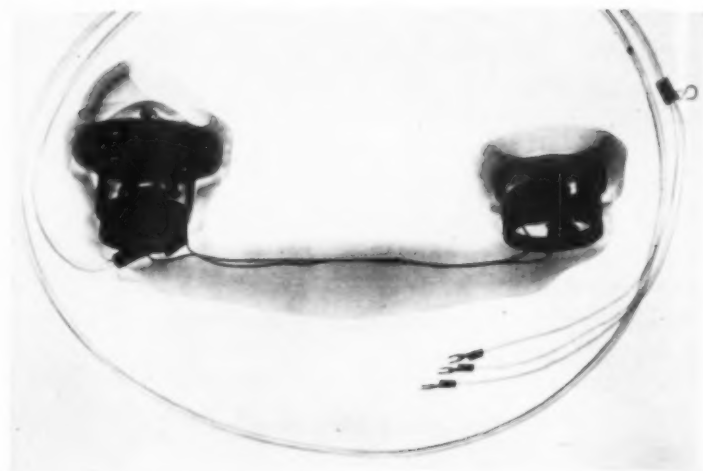
Because of the importance of the orientation of these very fine shrinkage cracks upon their detection by X-ray methods, it is sometimes desirable and often imperative to take two or more radiographs at different angles, in order that the defects presenting too small a difference in thickness for detection in one of them may be detected in the other, where the path of the radiation through the defect may have happened to coincide more nearly with its longitudinal axis.

We have utilized a simple penetrometer to study the sensitivity of an X-ray examination of



the various types and sizes of internal defects in steel. Upon a steel plate — say  $\frac{1}{2}$ -in. thick — are placed a number of steel gage blocks. The blocks are arranged side by side, and each successive block is thicker than the preceding one by a definite measurable amount. The resulting radiograph will show a series of bands of different intensity, varying in steps corresponding to the thicknesses of the gage blocks. By picking out the first band perceptible and knowing the thickness of the gage block corresponding to the band, a quantitative value is found for the minimum additional steel thickness detectable in a  $\frac{1}{2}$ -in. steel plate.

The same procedure should be repeated with other plate thicknesses varying from  $\frac{1}{4}$  in. to 1 in. At all times the voltage of the tube should be adjusted to give the optimum exposure condition for each particular thickness of steel. Within a known thickness range, therefore, the effective



*Telephone Handset Requires Skill on the Part of the Radiographer if Various Substances Are to Be Adequately Differentiated*

thickness of any defect, which is represented by a darker area on the negative, may be estimated. This is accomplished by knowing the total thickness of the material and the ratio between the photographic density at a point where no defects appear. Interpretation of

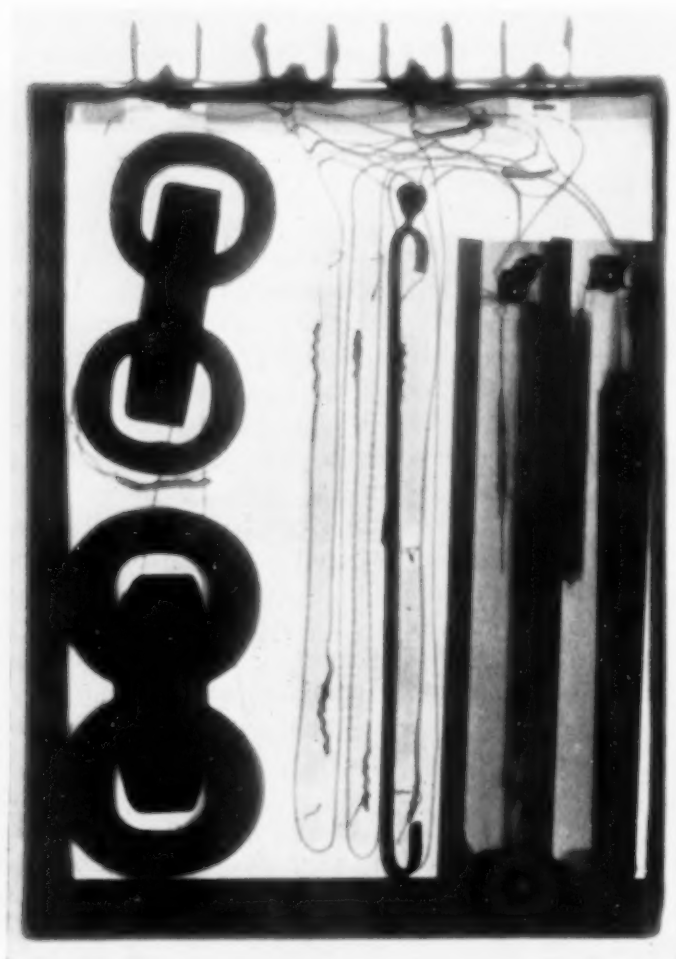
most X-ray negatives is, therefore, resolved into a quantitative instead of a qualitative study, and the procuring of accurate knowledge of internal imperfection is greatly facilitated by graphs such as the one on page 66.

This investigation demonstrated that in a thickness of  $\frac{1}{2}$  in. of steel, differences in thickness parallel to the path of the X-radiation representing 0.5% of the total thickness may be detected. For 1-in. steel thickness, the sensitivity of the X-ray method is in the neighborhood of 0.8 to 1% of the thickness, and for 2-in. to 3-in. sections defects representing a difference of 2% in thickness may be readily detected. The upper curve shows the minimum thicknesses of steel detectable for various total thicknesses of steel penetrated by the rays.

The lower curve shows the same data in a different form. The per cent of total steel thickness detectable is plotted against the total steel thickness. If an X-ray photograph of a casting or metal joint has an even density, it can then be estimated that any defects that are included but not detected are less than the minimum established by the data shown.

#### **Application to Industry**

Application of X-ray technic has proved extremely useful in a number of engineering fields. One of its most obvious advantages is



*Exograph of Equalizer, an Assemblage of Condensers, Resistances and Inductances in a Steel, Pitch-Filled Box. Full size*

that it does not require the destruction of the part under examination in order that the engineer may discover its true condition. This has led to important applications of X-ray analysis in the field of welding, and in the foundry.

Companies specializing in the production of large welded structures, pressure vessels for example, or foundries that produce large castings of an intricate character, find it economically impossible to produce an additional unit, costing hundreds and often thousands of dollars, to be used in a destructive test in order to assure the purchaser that he is getting a satisfactory product. However, by taking a series of radiographs of the completed product it is now possible for the manufacturer to check very accurately the quality of his work without destroying any of it and at a relatively low cost.



*Arrangement of Metallic Objects, Each With Film Holder Tied on, Surrounding Small Capsule of Radon, Which Emits Gamma Rays in All Directions in Equal Intensity*

In addition to providing a guarantee to the purchaser that he is getting a satisfactory product, the X-ray also shows the manufacturer where he may improve his product, for he can instantly discover what effect any change in his manufacturing procedure produces upon the soundness of his work. A third advantage to be gained from such an analysis lies in the additional reliability that

may be placed upon a product that has been X-rayed. Products of poor quality, although apparently sound as far as visual examination can determine, are often the cause of serious industrial breakdowns, with attendant economic losses, and sometimes with serious injury to workers. From a safety standpoint alone, the expense of radiographic examination of products that are to occupy important parts of engineering structures is justified, for by such examination, dangerously weak members may be eliminated during the manufacturing process.

Three exographs are reproduced on page 67 from many we have made on welded joints. The first shows a weld that has split open due to stresses incident to cooling the metal after welding. Such a condition may occur when the welding sequences are incorrect or through the use of jigs for holding the parts during welding that do not properly allow for expansion and contraction of the metal. Defects of this character may be overcome by changing the sequence of welding and by redesigning the jigs. Another type of defect very commonly encountered is porosity or gas pockets caused by trapping of gases in the weld metal during the welding process. By improving the welding technic through repeated X-ray examinations of welds made under various conditions, a joint of unusually high quality may be obtained even with bare wire electrodes. The remarkable improvement attainable by the X-ray method of attack on a problem of this character can be seen.

Similar technic may be employed to improve the quality of die castings. In the past, the commercial run of die castings have been subject to gas pockets, undetectable by surface examination. By varying the pressures and temperatures at which the castings are made and making X-ray examinations of the experimental die castings, the correct conditions for a high quality product may be easily established.

Cracks caused by a combination of internal stress and corrosion sometimes found in non-ferrous materials such as brass, may readily be detected by X-rays even when they are not visible to the eye. Soundness of test material can be established before any extensive program (such as creep testing) is embarked upon.

X-ray examination is particularly useful for making non-destructive examinations of assembled apparatus in order to determine the relationship of concealed parts. For example, in equalizers containing condensers, resistances, and various inductances completely impounded in pitch and assembled in a sheet-steel container, the position of the parts may be easily checked and voids in the pitch seal can be revealed. Similar applications of X-rays are obvious

for determining the position of the filament and grid in high-power transmitting tubes where the plate forms a heavy copper shell completely covering the other elements, or for checking the relation of parts in any metal-cased electron tube.

The X-ray method of examination may be applied with equal facility to materials of a non-metallic character as well as to metals. For example, an exograph of a slate panel clearly revealed unsuspected internal defects.

In telephone work, problems are often encountered that involve apparatus consisting of combinations of metals with non-metallic materials such as bakelite, hard rubber, phenol fiber, woven cotton, or silk. X-ray examination of such subjects is quite difficult because the tremendous differences in the densities of the materials give the radiologist a problem similar to the photographer's when dealing with a subject containing extreme highlights and deep shadows. An example is shown in the view of a telephone handset (page 68). Position of metallic elements and reinforcing wires can be distinguished, and yet the original film clearly shows details of the tinsel winding in the cord as contrasted with the woven covering! *(Continued on page 86)*



**Albert F. Shore**, inventor of the scleroscope, died on Jan. 17, at the age of 59 years.

**Radclyffe Furness**, superintendent of the open-hearth and forge departments of Midvale Steel Co., died Jan. 12, aged 67 years.

**John K. Schofield**, past chairman of Montreal Chapter and an executive of Edgar Allen Co. of Canada, died Jan. 16 of complications following appendicitis.

**W. C. Peterson**, a prominent member of the Society's Detroit Chapter in the early days, died on Dec. 21 after a lingering illness.

**Z. L. Sault**, charter member of the Boston Chapter, manager of Porter Forge & Furnace Co., died in November.

**Scott Lynn**, president of Sangamo Co., Ltd., died in Toronto, New Years Day.

## PERSONALITIES

**Fritz Eberle**, formerly head of the Metallurgical Research Division of Leeds & Northrup Co., has joined the Duquesne Works of Carnegie-Illinois Steel Corp.

**J. A. Kingsbury**, chief metallurgist, Bendix Products Co., has been made senior materials engineer for the U.S. Naval Gun Factory.

**Louis C. McNutt** is with the M. W. Kellogg Co. in Jersey City.

**Ray C. Skeel** has been promoted from assistant chief mechanical engineer to plant engineer for Truscon Steel Co.'s Pressed Steel Division.

**Frank K. Ziegler** is now Chicago district representative for Electro-Alloys Co.

**A. P. Hoelscher** has left the University of Iowa to take a teaching position in the School of Chemical Engineering of Purdue University.

**R. C. Diehl** is with the Wheeling Steel Co. in Steubenville.

**Fred Kasch** has left International Nickel Co. to become manager of Denver Ball Casting Co.

**Francis P. Whalen** has been transferred from the American Steel & Wire Co. to the U.S. Steel Corp. Research Laboratory.

**John F. Eckel** has accepted a position with the Western Electric Co.

**Bertrand S. Norris** has left Battelle Memorial Institute to become a graduate assistant at Penn State College.

**William F. Heesch** is president of Havanna Metal Wheel Co. He was formerly with French and Hecht.

**George Burrus, Jr.**, has been appointed junior metallurgist of the Spicer Mfg. Corp., Pottstown, Pa.

**W. M. Lindsey** is with Washburn Wire Co., Phillipsdale, R.I.

**James Hutton** is employed by the Lukus Co., Ltd., England, as supervisor of materials.

**C. H. Carpenter** has joined the Lee Wilson Engineering Co. of Cleveland.

**Stanley A. Richardson** has been appointed general sales engineer for Empire Sheet & Tin Plate Co. **William Fox** has replaced Mr. Richardson as chief metallurgist.

**Everett L. Reed** is research metallurgist in the Ordnance Department at Watertown Arsenal.

**L. S. Cope** has been promoted from metallurgist to general superintendent, National Screw & Mfg. Co.

**William J. Mackenzie** is head of the Alloy Steel Division of Youngstown Sheet & Tube Co. in the Chicago offices.

**Louis Jordan** has left the Bureau of Standards to serve as secretary of the Iron and Steel and Institute of Metals Divisions of the American Institute of Mining and Metallurgical Engineers.

**T. N. Holden** has been made sales representative in New York City for the Despatch Oven Co.



★

**SHE'S A PARTNER IN A  
GREAT AMERICAN BUSINESS**



SHE is one of 850,000 owners of Bell System securities. They are typical Americans—some young, some middle age, some old. They live in every part of the nation.

One may be a housewife in Pennsylvania. Another a physician in Oregon—a clerk in Illinois—an engineer in Texas—a merchant in Massachusetts—a miner in Nevada—a stenographer in Missouri—a teacher in California—or a telephone employee in Michigan.

For the most part, Bell System stockholders are men and women who have put aside small sums for saving. More than half of them have held their shares for five years or longer. More

than 650,000 of these 850,000 security holders own stock in the American Telephone and Telegraph Company—the parent company of the Bell System. More than 225,000 own five shares or less. Over fifty per cent are women. No one owns as much as one per cent of the stock of A. T. & T. In a very real sense, the Bell System is a democracy in business—owned by the people it serves.

Over 270,000 men and women work for the Bell System. One person out of every 150 in this country owns A. T. & T. securities or stock and bonds of associated companies in the Bell System.



**BELL TELEPHONE SYSTEM**

# NITRIDING

(Continued from page 39)

stainless character of the nitrided edge, and carbides are precipitated in a finely dispersed form. This gives a sorbitic appearance to the structure, together with free ferrite.

A chromium iron (26.3% Cr, 0.26% C) was more difficult to harden, owing to the very stable oxide film on the surface, which resisted the penetration of atomic nitrogen. Even after pickling the steel in hydrochloric acid before nitriding, it was found that the oxide film re-formed in local areas on the surface of the steel. The surface was dull gray where hardening had occurred, due to the diffusion of nitrogen, while the parts which did not harden remained bright. The microstructure was similar to those just described except that many particles of free carbide are present.

Best results on the austenitic 18-8 steel (17.3% Cr, 7.4% Ni, 0.11% C) were had by nitriding 48 hr. at 1035° F. at a pressure of 12 in. water gage. Maximum hardness of 1300 Vickers Brinell occurred 0.002 in. below the surface, and half the added hardness was lost at a depth of 0.005 in. Substantially the same results were obtained at normal gas pressures on an 18-8 with 1.0% Al.

Nitriding characteristics of the lower chromium, higher nickel steels (13 to 15% Cr, 9 to 12% Ni, 0.10% C) were somewhat similar to the

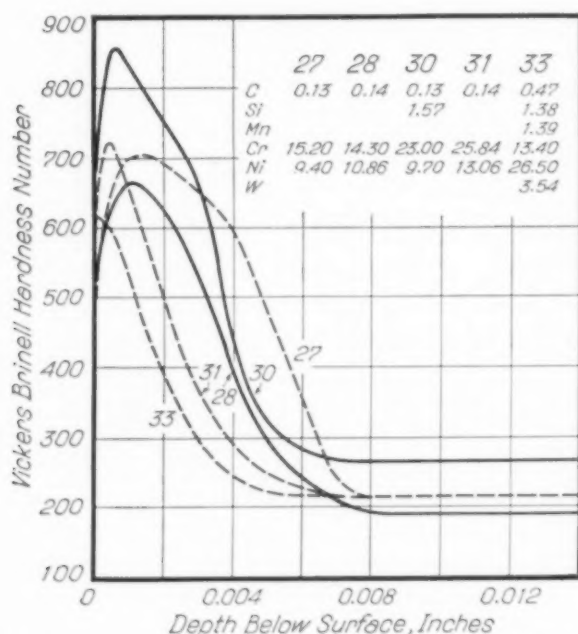
above, although sometimes it was evident that the higher nickel content had a restraining effect on the hardening of the steels. A very high surface hardness of 1250 Vickers Brinell was obtained in a 13-12 chromium-nickel steel after copper plating prior to nitriding at 1035° F.

Higher chromium alloys (23 to 26% Cr, 10 to 13% Ni, 0.13% C) contain a stable form of austenite, and nitride with difficulty. Best results were had at 1175° F., which gave surface hardness of 860 and case depth of 0.006 in. Hardness vs. depth curves of these alloys are shown on the curves below.

Two heat resisting steels used for gas engine valves were also nitrided. One contained 14.2% Cr, 13.8% Ni, 2.1% W and 0.30% C, and the other 13.4% Cr, 26.5% Ni, 3.5% W and 0.47% C. (The latter is shown as No. 33 on the curve sheet.) Nitride hardening of the valve stems increases the wear resistance. The greatest hardening occurred when these steels were nitrided at 1125° F. at a pressure of 12 in. water gage. It was found that the hardness of the surface varied from 580 to 810 Vickers Brinell, and this variation also occurred in the copper-plated steel after nitriding at the same temperature.

The original structure of twinned austenite in 18-8 is still apparent after nitriding, but the structure in the case consists of finely dispersed carbides, which gives it a sorbitic appearance. This is caused by the decomposition of austenite, and the formation of many insoluble particles of chromium nitride, which are firmly fixed in the crystal lattice. The chromium content of the matrix is thus depleted, until ultimately the austenite breaks down, with the formation of  $\alpha$ -iron (ferrite), and the carbides (which were previously retained in solid solution in the  $\gamma$ -iron) are precipitated in a finely dispersed form in the ground mass. The nitrided edge is thus readily revealed on etching with dilute nitric acid, while the core is unattacked, as it remains in the austenitic condition.

The structure shows an appreciable quantity of fine carbides, owing to the high chromium content of the steels, while the precipitation of carbides or nitrides along the crystallographic planes of the original austenite reveals the twins that were originally present. Other micros show that the penetration of nitrogen takes place by the formation and deposition of particles around the grain boundaries and in the slip planes of the austenite. The grains of austenite adjacent to the nitrided edge reveal Neumann lamellae when the core is etched electrolytically.



As Constitution of Austenitic High Chromium-Nickel Steels Falls Further Away From the Martensitic Border Line, Nitriding Becomes More and More Difficult



## **MOLY increases the pay load by decreasing the dead load**

FREIGHT haulage is the railroad's "bread and butter." One way to lower operating costs is through lighter, yet stronger, load-carrying rolling stock. It permits larger pay loads per car or more cars per train; less strain (particularly in starting) and less fuel consumption.

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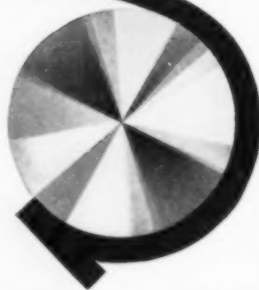


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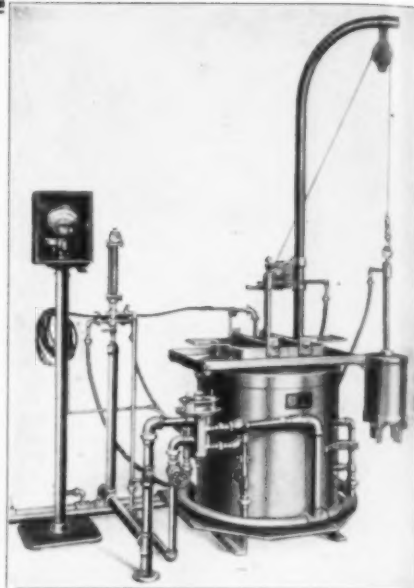
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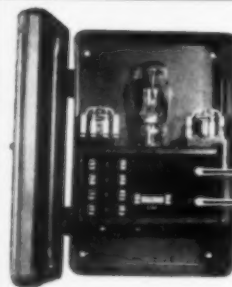
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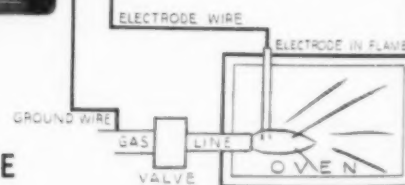
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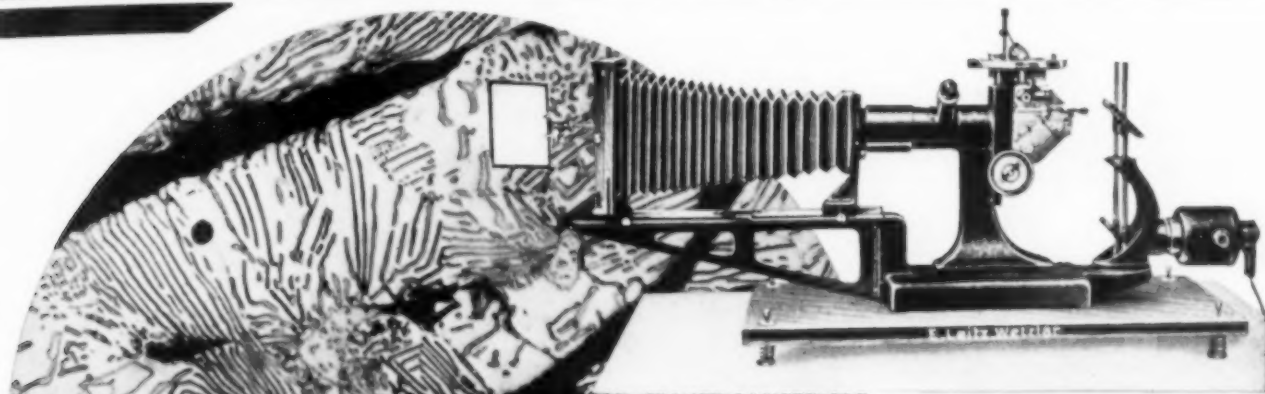
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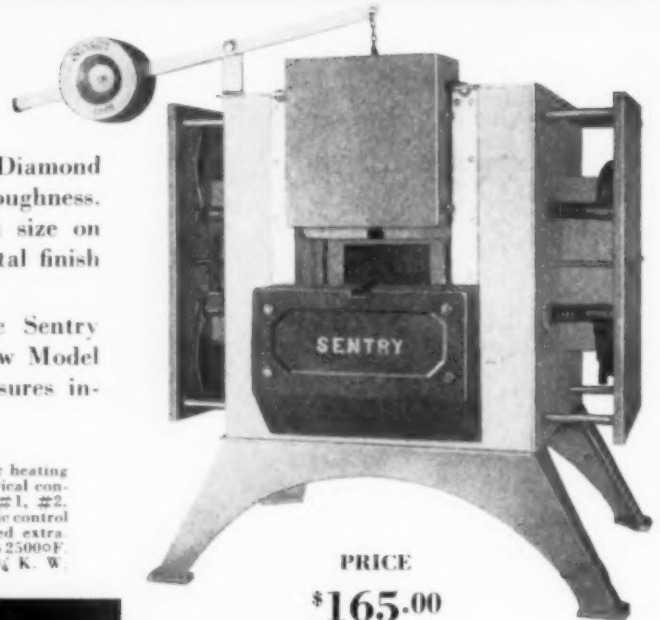
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# **TAM** Medium Carbon **F.** FERRO **C.** CARBON **T.** TITANIUM

February, 1936; Page 77

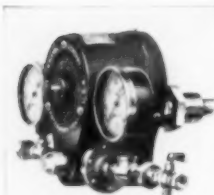
# PRECISION

## Temperature Control

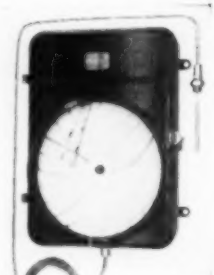
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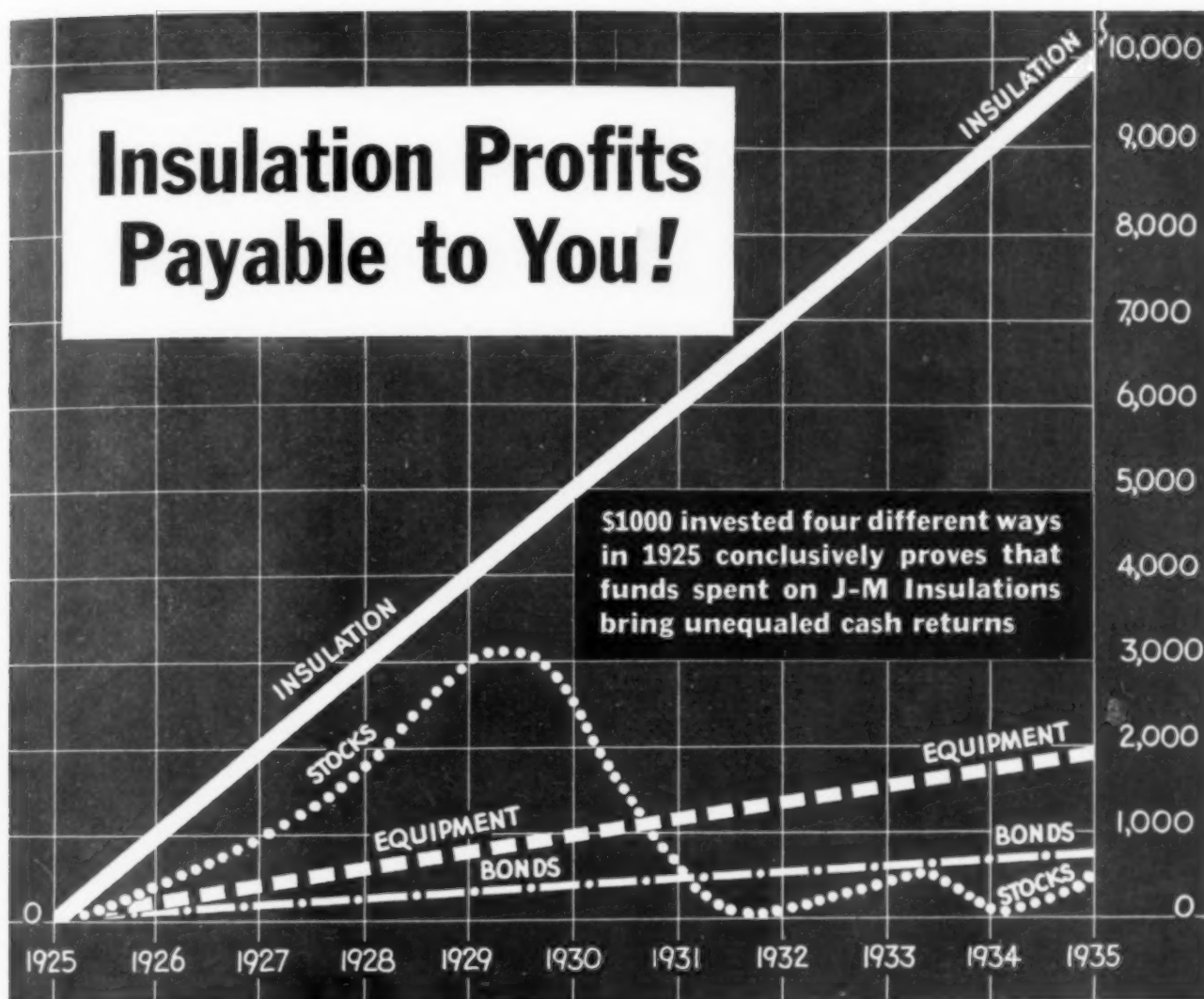
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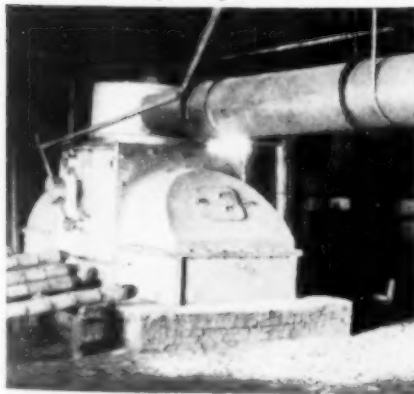
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**"FLEETWELD 5"** welds in all positions producing weld metal with tensile strength of 65,000-75,000 lbs. per sq. in.; ductility of 20%-30% elongation in 2"; impact resistance of 30-70 ft. lbs. (Izod); fatigue resistance of 28,000-32,000 lbs. per sq. in.; density of 7.84-7.86 grams per c. c.; resistance to corrosion greater than mild steel. Welds can be flanged or bent cold, also forged.

**"FLEETWELD 6"** for flat position welding only. Welds more than meet A.S.M.E. Boiler Code, Class 1 requirements. Welds have approximately 65,000 lbs. per sq. in. tensile strength; average ductility, 25%-35% elongation in 2"; impact resistance, 30-60 ft. lbs. (Izod); fatigue resistance, 28,000-32,000 lbs. per sq. in.; density, 7.85-7.86 grams per c. c.; resistance to corrosion greater than mild steel.

**"FLEETWELD 7"** for all positions, especially for high speed single pass welding, and where fit-up of work may be poor. Welds show tensile strength of 70,000-80,000 lbs. per sq. in.; ductility, approximately 20% elongation in 2"; impact resistance, 25-30 ft. lbs. (Izod); fatigue resistance, 25,000-30,000 lbs. per sq. in.; density, 7.80-7.85 grams per c. c.; resistance to corrosion comparable to mild steel.

**FREE** samples of "Fleetweld" electrodes are available. Requests for samples should specify type of "Fleetweld" desired.

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## PLASTIC FLOW

In view of the possibility of hardening after cold work (plastic deformation) it is clear that the relationship of softening to heat treatment cannot be a direct ratio.

Slip is most obvious in carbonyl iron and Swedish iron both on the surface and in the interior of crystals, and is least visible in Armco ingot iron and mild steel. The principal visible form of movement in these materials below 600° F. is by slip, which diminishes with increasing temperature up to 1550° F.

At moderate temperatures, such as 850° F., initial deformation of steel, a polycrystalline aggregate, occurs by slip. Re-bonding occurs in a new position, but the process is not without a marked effect on the atoms adjoining the slip plane, as is shown in the permanent alteration of the properties of the material.

X-ray examination suggests that the lattice of a crystal grain can be strained to a degree corresponding to the elastic limit. Beyond this point slip occurs and the stress is relieved to a value possibly slightly less than that at the point of slipping. In order that slip may continue the stress must again build up to a value as great as or greater than the previous elastic limit. Slip is not a continuous movement, but occurs in a series of steps which correspond to lateral movements on groups of parallel planes. In terms of the atomic size this movement is appreciable, for the blocks have dimensions corresponding to several thousands of atoms.

Deformation at such moderately high temperatures results in recrystallization. (Recrystallization is regarded as including any process which results in crystalline recovery.) As far as its ultimate effect is concerned, the subject of recrystallization is divisible into three sections: (a) Grain growth, (b) generation of new crystals by full recrystallization, (c) division of existing crystals into smaller units — "sub-crystallization." Thus, deformation by creep tends to produce fragmentation of the crystals, whereas the result of prolonged treatment at an annealing temperature results in more or less complete crystalline recovery.

In the case of slight deformation at an intermediate range of temperature, re-orientation effects are set up in the strained crystals without

(Continued on page 82)

# HARRIS Patent No. 2,022,283

## Obsoletes All One-piece Trays in

## Three Rail Pusher Furnaces . . .



**A** One piece annealing, carburizing or heat treating tray on three rail pusher furnace. Note that center rail is low and that the tray is riding the outer rails only. The stress in this position is four times greater than with all rails bearing.



**B** Same as above with center rail high and tray cantilevered. This stress can approximate seven times normal stress with three rails bearing.



**C** Harris hinged tray. Although center rail is low as in Fig. "A" the hinged tray distributes the load on three rails with stresses only one-quarter that of one-piece tray.



**D** Harris hinged tray. Center rail is high as in Fig. "B" but weight is uniformly distributed and stresses approximate one-seventh that of tray shown in Fig B.

IT is perfectly obvious that no set of three parallel rails whether "dry skid" or rollers remain perfectly level on the top side under temperature in the furnace. It would be next to impossible to make them remain straight even if they were cold and set on a brick floor.

IN other words there is no such thing as three point alloy support in a pusher furnace. Alloy trays while hot conform, *strain themselves in seeking conformation*, with irregularities of support, which flexing may bring on earlier fatigue failure than would occur where stresses reduced by making is impossible for the tray to work on a loaded span wider than two rails.

THE above cuts are purely diagrammatic and a dry skid rail is shown for simplicity. The same principle applies regardless of rail design or what type of load is carried on the trays.

THE Harris patent is not intended to cover a specific mechanical design for correlating two or more sections of a tray to move as a unit through a furnace. Whether these trays are hinged, articulated or hold on to each other's coat tails is unimportant as long as they are free to flex and eliminate the stress of changeable span, which is the purpose of the development. This idea can be carried out with trays of two, three or more pieces and in furnaces of almost unlimited width with a large number of rails, under this patent.



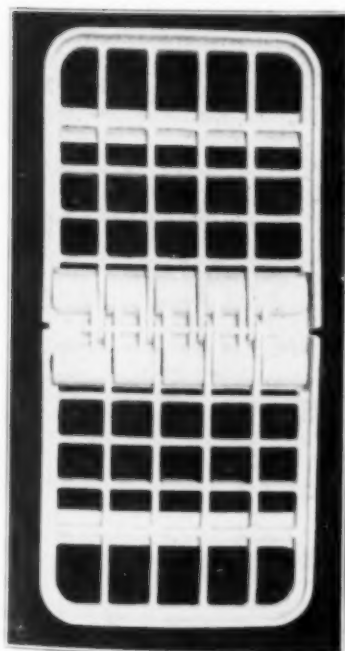
● The design shown at left is only one type of hinged tray. We have a number of successful installations and many repeat orders. The fact is that any one piece tray in any three rail furnace is as obsolete as the dodo bird. The Harris hinged tray makes it possible to design materially lighter trays for handling a given load, which trays will have longer life and have the added advantage, in the design shown, of the two sides being interchangeable permitting unit replacement and getting maximum salvage out of used parts.

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## PLASTIC FLOW

the formation of new grains. The phenomenon is somewhat analogous to the results of re-annealing deformed material, in that lightly deformed material does not recrystallize, but undergoes re-orientation within the crystals and consequently considerable readjustment of the internal grain boundaries is necessary to produce a stable system. Grain growth, therefore, occurs on the part of favorably oriented crystals (and can apparently occur without formation of new grains).

The normal manner of failure in test pieces of iron and mild steel fractured below 750° F. is by transcrystalline rupture. In creep tests at 750° F. taking up to 10 days for fracture, Armco ingot iron exhibits intercrystalline cracking, but no characteristic intercrystalline failure is found in the other materials tested at this temperature. Transcrystalline rupture probably results from the fact that the center of a crystal, owing to geometrical conditions, deforms more easily than the material in the region of the grain boundaries.

Surface cracks show little tendency to spread into the material except in Armco ingot iron. The tests on Armco ingot iron also show that intercrystalline cracks may develop by internal separation of the grains.

Failure by intercrystalline cracking is found in materials subjected to internal strain accompanied by corrosive conditions, and in alloy steels fractured by prolonged application of stress at elevated temperatures. In the latter case the crystals have been stiffened by alloying additions, but alloying does not appear to strengthen the grain boundaries.

The present work suggests that intercrystalline cracking occurs in a material which does not accommodate its localized differences in stress by recrystallization. The facility of recrystallization prevents a material from becoming unduly work-hardened and does, in general, hinder the formation of cracks which lead to rupture.

In soft steel at temperatures below 600° F. the presence of the harder constituent, pearlite, probably has a marked stiffening effect on the ferrite grains, and this effect diminishes with rise of temperature up to the  $A_1$  point.

Apart from the mode of rupture and degree of recrystallization, spheroidization of the car-

*(Continued on page 84)*



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(Allegheny Metal is licensed under Chemical Foundation patents Nos. 1,316,617 and 1,336,378)

## CARBON-MOLYBDENUM STEEL

Recently introduced steels containing small quantities of molybdenum are notable for their excellent tensile strengths and high creep strength, or resistance to slip between adjacent grains when stressed at high temperatures. The usual molybdenum content of such steels is .40% to .70%.

## MUREX CARBON-MOLYBDENUM WELD METAL



### PHYSICAL PROPERTIES

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Ultimate Strength	73,000 p.s.i.	Reduction in Area	66.6%

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Carbon	.12%	Molybdenum	.48%
Silicon	.08%	Manganese	.64%
Phosphorus and Sulphur	less than .035%		

Murex Carbon-Molybdenum .50 Electrodes are used widely in welding piping for high-pressure and high temperature services. Rapid in operation, they can be depended on consistently to produce clean, sound deposits with physical properties equal in every respect to those of the metal being welded. In fact, the particular properties of the deposit depend to a great extent on the carbon, molybdenum and manganese contents of the parent metal. When welding high strength manganese-molybdenum steel, for example, the weld metal may develop tensile strengths as great as 97,000 lbs. per sq. in.

Murex Electrodes for welding alloy steels . . . including Cromansil, Cor-Ten, 2½% Nickel, .85% Nickel, 4% to 6% Chrome . . . have found wide acceptance throughout industry. All are standard Murex Electrodes and can be furnished promptly from stock.

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## PLASTIC FLOW

bide is a factor. After long stay at 650 to 1200° F., and after short time tensile tests at 1050° F. and 1200° F. the pearlite present in mild steel begins to spheroidize. If this action is completed, the iron carbide is aggregated into rounded globules, which have little stiffening effect on the continuous ferrite phase.

The present work shows that in 24 hr. at 1025° F., spheroidization of the carbide in pearlite under the deformation produced by a load of 9000 psi. is quite appreciable and in marked contrast to the inappreciable amount produced in an unstressed specimen. It thus appears that the rate of diffusion of the carbide has been greatly increased by the deformation.

The samples of Swedish iron and of Armco ingot iron contain larger and more numerous non-metallic inclusions than the mild steels. The carbonyl iron is apparently free from included matter. In no case does it appear that the mode of deformation and fracture has been directly influenced by individual pieces of non-metallic material. An indirect effect is undoubtedly present in the case of Swedish iron which tends to split into longitudinal fibers parallel to the direction of the non-metallic inclusions. Intercrystalline cracking of Armco ingot iron is not connected with visible included matter, but may possibly be associated with the oxygen and nitrogen contents and a proportion of other constituents.

The effect of the process of manufacture of the various materials is revealed by differences in the mode of deformation in long-time creep tests. Mild steel shows little tendency to develop intercrystalline weakness or to split longitudinally into fibers; it thus appears that the presence of carbon during manufacture has kept the steel free from some of the defects that arise from the presence of oxides. Swedish iron shows an ease of recrystallization and considerable ductility, but a marked tendency to form longitudinal fibers under the action of deformation. The mode of manufacture has caused an unusual distribution of the impurities in Armco ingot iron, which is the least ductile of all the materials and is characterized by a tendency to develop intercrystalline cracking at high temperatures. Carbonyl iron shows no tendency to split longitudinally into fibers, but is otherwise very similar in behavior to Swedish iron.



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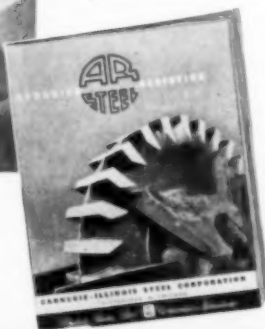
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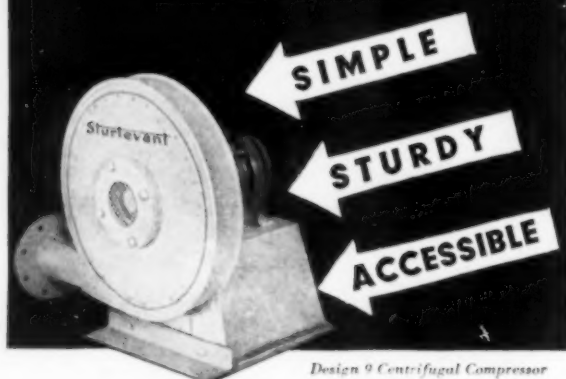
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## RADIOGRAPHY

During the last two years industrial use has been made of gamma rays for the examination of metals for defects in sections of steel as thick as 10 in. Gamma rays, as mentioned previously, are electromagnetic rays similar to X-rays, but their wave-lengths are even shorter. They are produced by the disintegration of the atomic nuclei of radium. The commercial source of such radiation is "radon," a gas obtained from certain solutions of radium salts. This gas has the ability to radiate gamma rays in the same manner that radium does, but the amount of radiation produced decreases rapidly, so that its effective life is but a few days. A small capsule of radon gas no larger than a 22-caliber bullet may be rented from the manufacturers at small cost, and will furnish sufficient gamma-ray radiation to allow a number of heavy metal parts to be radiographed that could not be penetrated by X-rays.

The technic is simple, as shown by the last view where a number of objects, to each of which a film is attached, are arranged about a radon capsule. Of course the sensitivity of the method is not as great as that attainable with X-rays on sections sufficiently thin for X-ray examination, for we have no control over the "hardness" of the rays emitted by the radon gas, and consequently cannot readily distinguish small differences of density. For example, a gamma-ray picture of a steel penetrometer, when compared with an exograph of the same subject, indicates that the steps representing different thicknesses of steel are much more sharply distinguishable in the exograph. However, for the examination of sections heavier than those that can be readily X-rayed, gamma rays give excellent results. For example, wiped lead joints for joining a cable with a loading-coil case have been studied with gamma rays. Such a joint must be of extremely high quality if corrosion and moisture complications are to be avoided. A gamma-ray examination can be used to reveal any defects present in the joint, whereas X-rays do not penetrate it.

In conclusion it may be said that within the well defined limits of usefulness set forth in this paper, we have in X-ray examination of engineering structures a useful non-destructive test of quality. Gamma rays may also be used in certain applications to reveal hidden defects where these defects might not be readily revealed by X-ray examination.

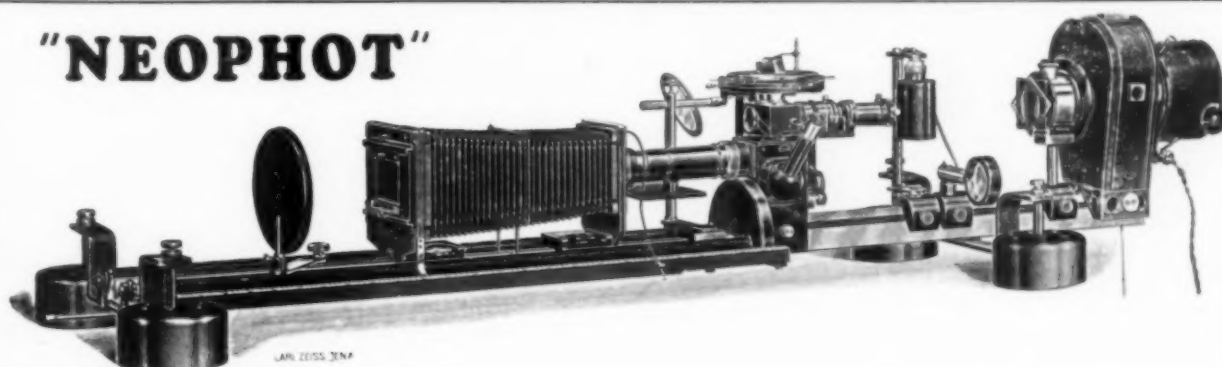


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## COPPER HOUSES

(Continued from page 46)

To hold the copper wall plates firmly in place and eliminate all tendency for vibration and rattling, yet provide full freedom for expansion and contraction with temperature, several spiral springs are fastened to the inside vertical center line of each plate. The other ends are hooked over a 1½-in. angle running vertically between studs. The tension of these springs draws the plate inwardly and at the same time brings it firmly into contact with the extruded bronze strip at the edges.

This building is roofed with the usual 16-oz. sheet with standing seams, laid on 7/8-in. tongue and grooved sheathing, supported by wooden rafters and insulated with felt paper and 4 in. of rock wool.

Inside wall surfaces are plastered on metal lath, and the 4-in. open space is filled with spun-glass insulation. This construction for outside walls transmits only 0.08 B.t.u. per hr. per sq.ft. per °F. difference in temperature inside to outside. Heat transmission through metallic studs is minimized by plaster on inside and the line contact between extruded shape and flanged copper at the outside. Condensation on the inner surface of these walls need not be feared in winter, as modern houses are completely air conditioned and humidity is under control at all times and temperatures.

Copper houses are painted in any color scheme desired, except, of course, the roof, which gradually acquires the patina which is so attractive. (This patina can now be artificially formed on the sheets prior to erection.)

While the copper walls in the Bethesda house are considerably more expensive than wood and probably more expensive than stucco, they are practically equal in cost to brick veneer and are less expensive than solid brick. However, we are not advocating copper houses from the standpoint of cheapness, but for their durability, taken in a broad sense. They are really reasonable for what you actually get in them — a structure that is weather-proof, rust-proof, fire-proof, lightning-proof, sound-proof, and termite-proof.

The construction principles used on the copper house can be applied to almost any type of design, and can be built by orthodox building methods and skilled building tradesmen. No difficulties or extra costs are involved in erection.